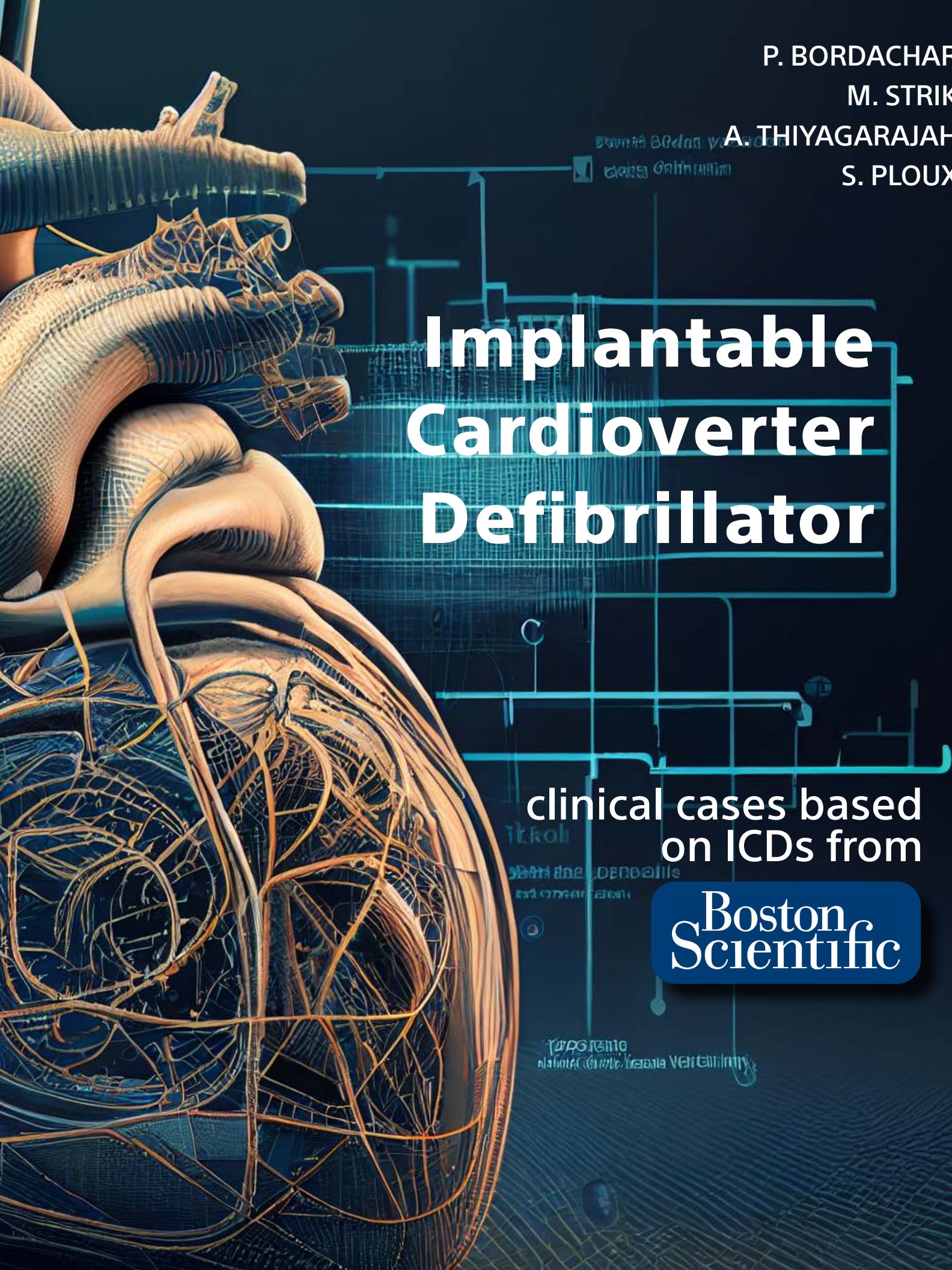
P. BORDACHAR
M. STRIK
A. THIYAGARAJAH
S. PLOUX



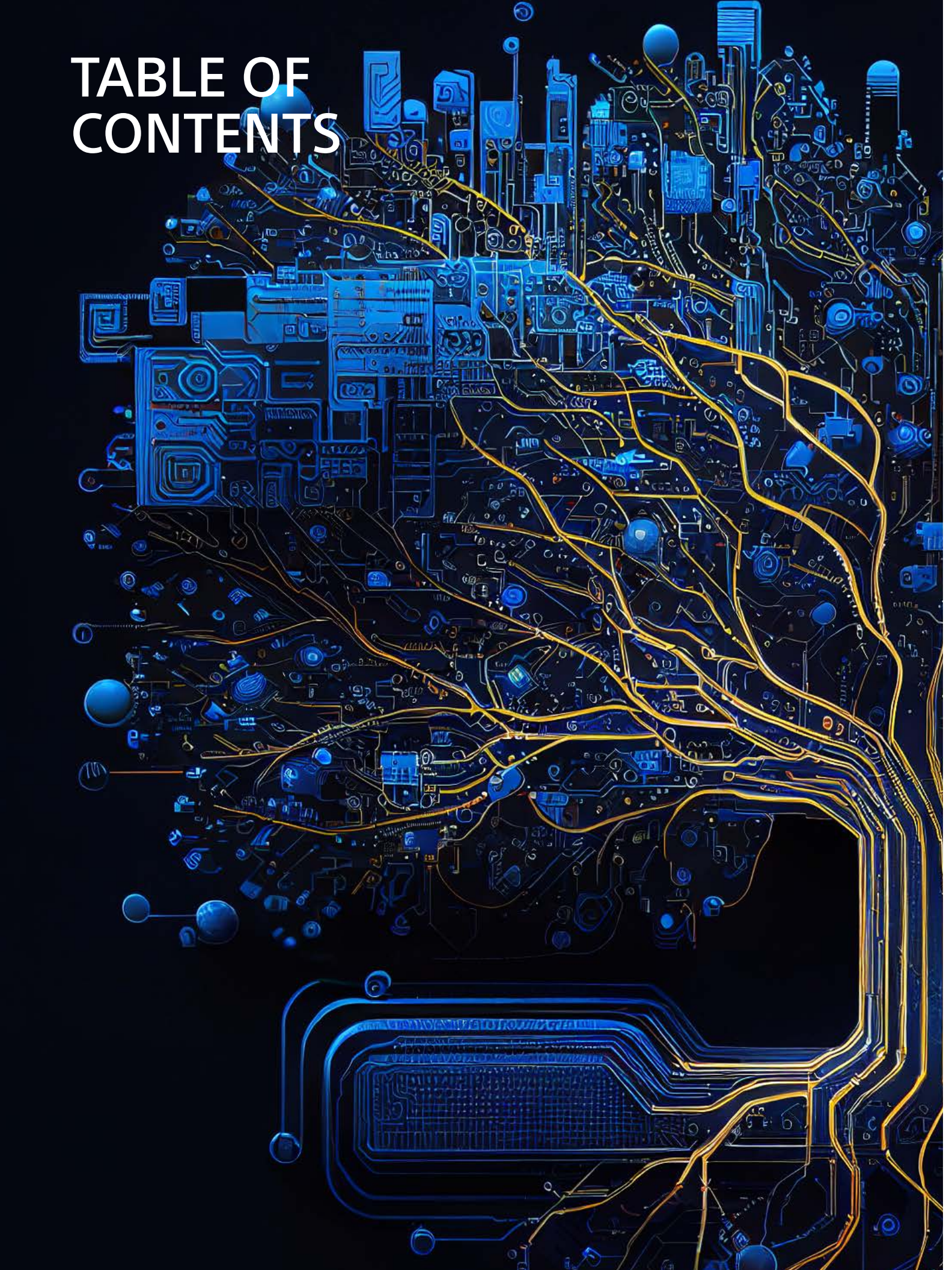
Implantable Cardioverter Defibrillator

clinical cases based on ICDs from

Boston Scientific

TABLE OF CONTENTS

TABLE OF CONTENTS



Chapter 3 205

Discrimination

Chapter 4 317

Oversensing

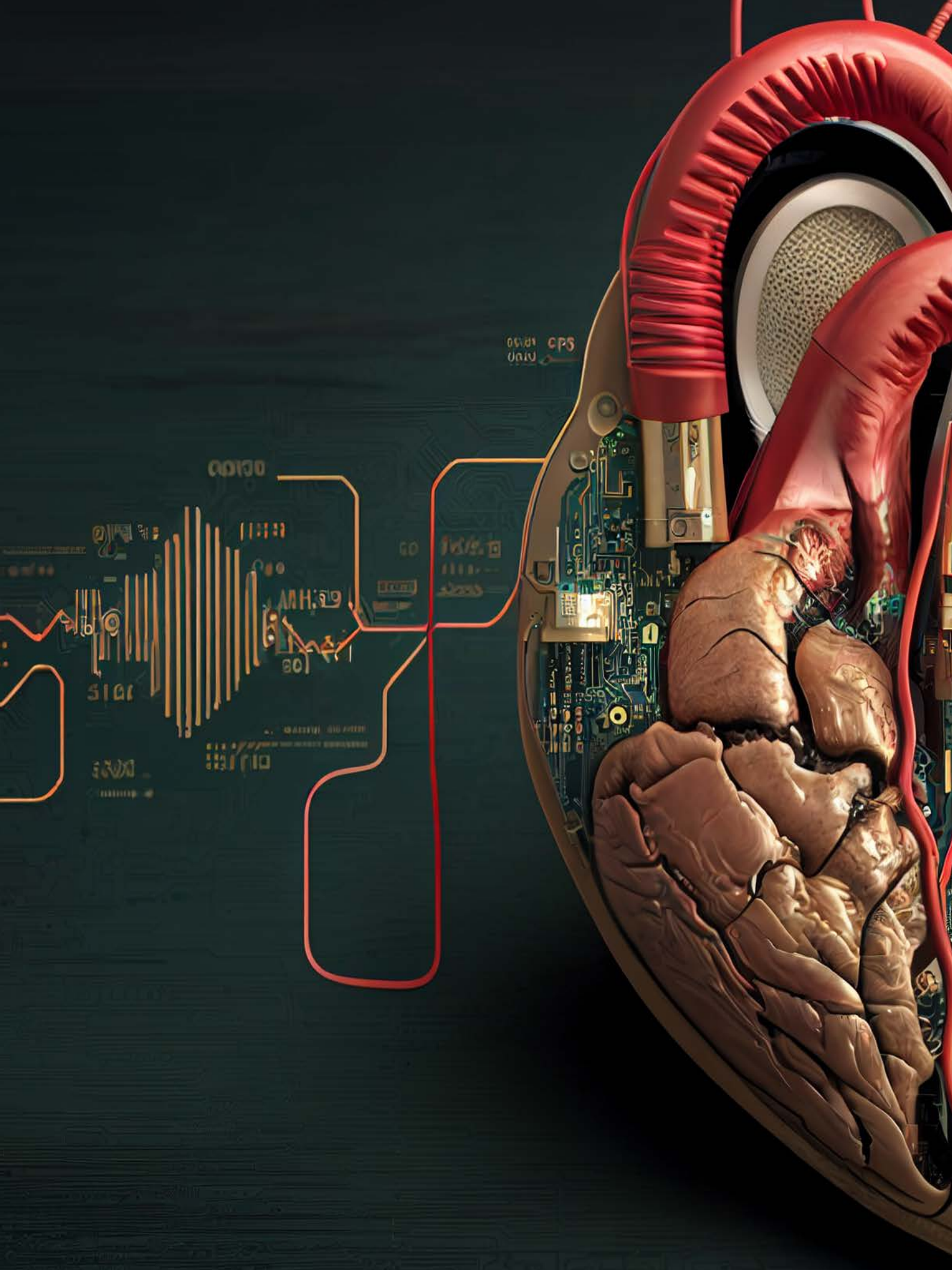
Foreword

The Stimuprat team is delighted to offer you this book on the specific features of interrogation and programming of Boston Scientific™ automatic implantable defibrillators.

Much more than the functioning of the devices themselves, which has changed little, recent years have seen significant developments in terms of programming rules, with a particular focus on strategies to reduce the number of inappropriate or unnecessary therapies as far as possible. That's why we wanted to update the first version of this book with episodes from the most recent platforms. This book is divided into several chapters (counters, therapies, discrimination, oversensing), each with demonstrative clinical cases covering the basic rules of defibrillator programming, as well as the specific operating and programming features of Boston Scientific™ devices.

Optimal programming requires in-depth knowledge of the algorithms used by the various manufacturers.

Enjoy your reading!



Chapter 1

Counters

1 Detection and treatment of a VF episode

Patient

- male with ischemic cardiomyopathy; implanted with a Resonate triple-chamber defibrillator

Summary

- episode classified in the VF zone
- 41 joule shock with a charge time of approximately 10 seconds
- 76 Ohm shock impedance (single-coil lead)

EGM layout

1 sinus rhythm and biventricular pacing (AS, RVP-LVP)

2 spontaneous, very rapid, polymorphic ventricular arrhythmia; the first 2 cycles are classified as VT, the following cycles as VF

3 V-Epsd marker; 8/10 criterion fulfilled for VT zone (2 cycles in VT zone + 6 cycles in VF zone); initial detection duration for VT zone starts on this beat

4 on this cycle, the initial detection window for the VF zone is satisfied (8 cycles in the VF zone); the initial detection duration for the VF zone begins on this beat; the VF zone duration takes precedence over the VT zone duration; even if the VT zone duration ends before the VF zone duration, if the 6/10 criterion is satisfied for the VF zone, the VT zone therapies are suspended until the VF zone duration ends.

5 persistence of arrhythmia detected in the VF zone for the initial duration of 5 seconds in the VF zone (V-Detect)

6 start of capacitor charging

7 ventricular sensing remains acceptable during charging, with the exception of a few under-sensed cycles explaining the VT markers; criterion 6 out of 10 remains fulfilled during charging.

8 end of charge; this charge lasted approximately 10 seconds, with the output of the pending shock equal to the maximum output of the device

9 a refractory period of 135 ms begins at the end of the charge; the first cycle following this refractory period is not counted (--)

10 the following 2 cycles are fast (VF), the shock diversion window has elapsed (500 ms after the end of charging); criterion 2/3 met.

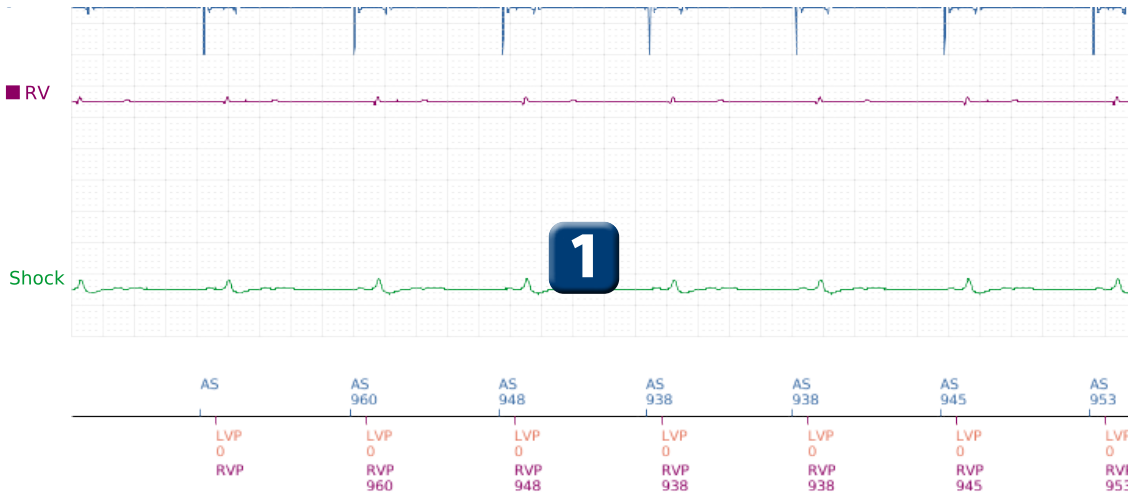
11 41 Joule shock delivered on the second cycle (synchronized to the R wave)

12 the first atrial cycle following the post-shock refractory period (500 ms) is not counted (--)

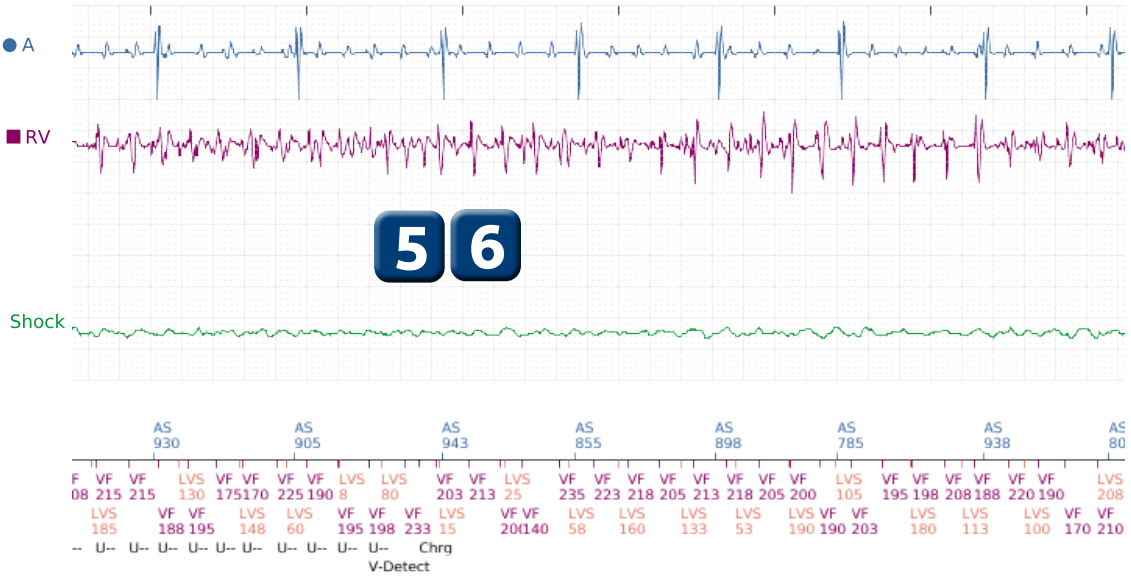
13 the first ventricular cycle following the post-shock refractory period is not counted (--)

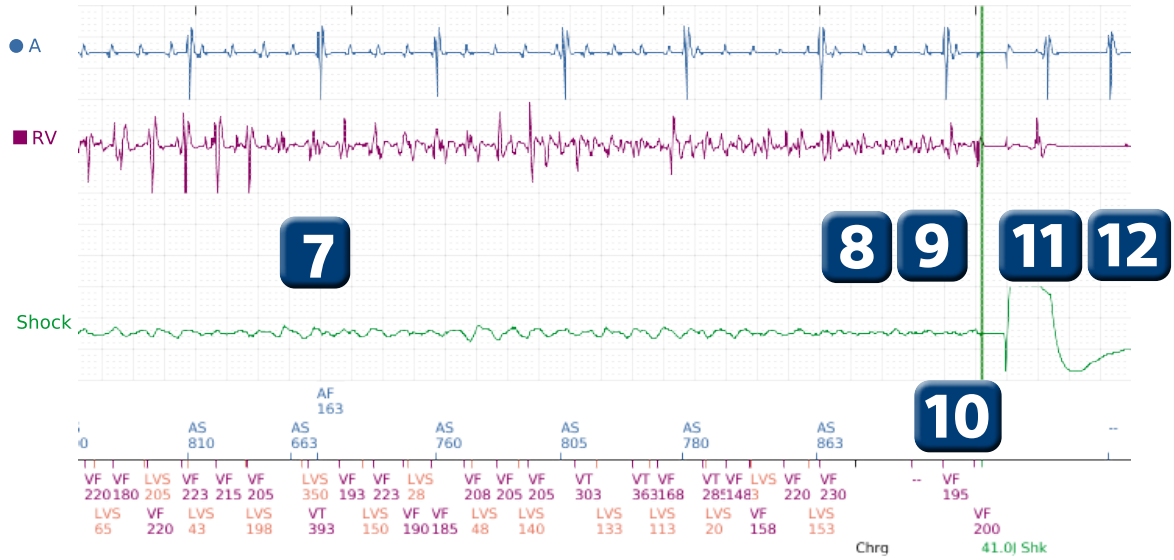
14 effective shock and termination of polymorphic ventricular arrhythmia

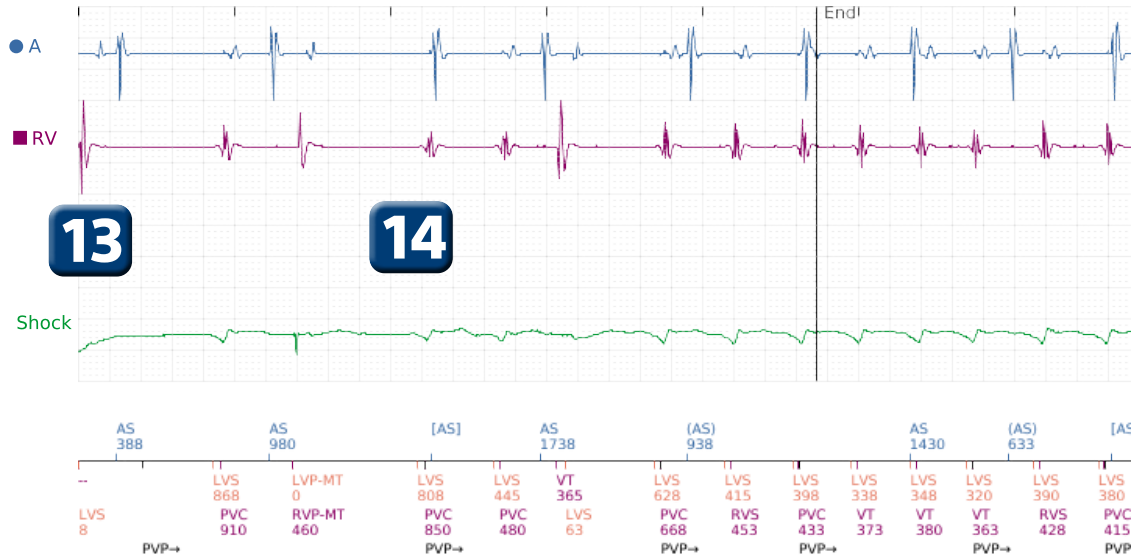
15 end of recording, although no end-of-episode marker is displayed

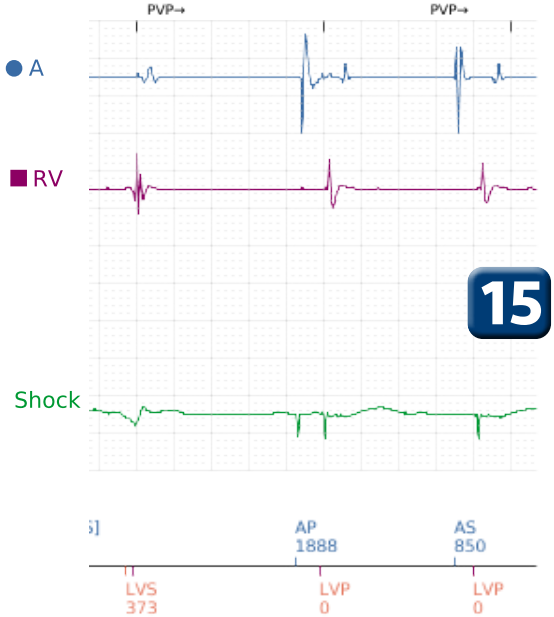

RV
Shock
1
AS
AS 960
AS 948
AS 938
AS 938
AS 945
AS 953
LVP 0 RVP
LVP 0 RVP 960
LVP 0 RVP 948
LVP 0 RVP 938
LVP 0 RVP 938
LVP 0 RVP 945

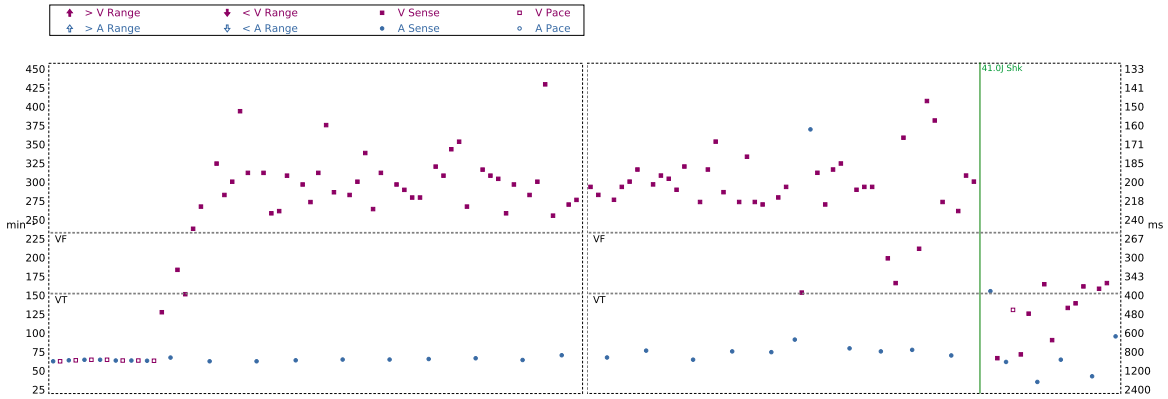

A
RV
Shock
Attempt
2
3
4
AS 958
(AS) 898
(AS) 960
AS 960
AS 948
AS 933
AS 933
V-Epsd


A
RV
Shock
5
6
AS 930
AS 905
AS 943
AS 855
AS 898
AS 785
AS 938
V-Detect


A
RV
7
8
9
11
12
Shock
10
AF 163
AS 810
AS 663
AS 760
AS 805
AS 780
AS 863
Chrg
41.0J Shk


End
A
RV
13
14
Shock
AS 388
AS 980
[AS]
AS 1738
(AS) 938
AS 1430
(AS) 633
PVP→


A
RV
15
Shock
AP 1888
AS 850
LVS 373
LVP 0
LVP 0



LATITUDE™ Patient Management - Event Detail Report	Report Created: 16 Jan 2023

Boston Scientific

Date of Birth:
Device: **RESONATE CRT-D G424/490880**
Clinic:
Search Tags:
Tachy Mode: **Monitor + Therapy**

Latest Device Transmission: **15 Jun 2021 03:22 CEST**
Last Office Interrogation: **19 May 2021**
Implant Date:

V-42: 20 Apr 2021 00:54, VF, A Rate: 64 min^{-1}, V Rate: 321 min^{-1}

Detail

VF Event Onset

Avg A Rate	64 min^{-1}
Avg V Rate	321 min^{-1}
Detection	Rhythm ID
Template	13 Apr 2021 18:29
RhythmMatch™ Threshold	94 %

At V-Detect

Avg A Rate	65 min^{-1}
Avg V Rate	297 min^{-1}
Rate Zone	VF
Stability	(19 ms, Off)
V>A Rate	(True, Off)
AFib	(False, Off)
RhythmID Correlated	False
RhythmMatch™	Too Fast
SRD Met	(False, Off)
ATP Timeout	False

Attempt 1, 41 J V Shock

Elapsed Time	00:00:06
Shock Information	
Charge Time	9.8 s
Lead Impedance	76 Ω
Lead Polarity	Initial

Event Ended 00:00:47

Points to remember

- this first trace illustrates the primary function of an implantable defibrillator: detection and treatment of ventricular fibrillation (an arrhythmia that is initially extremely rapid, polymorphic and disorganized) with a shock.

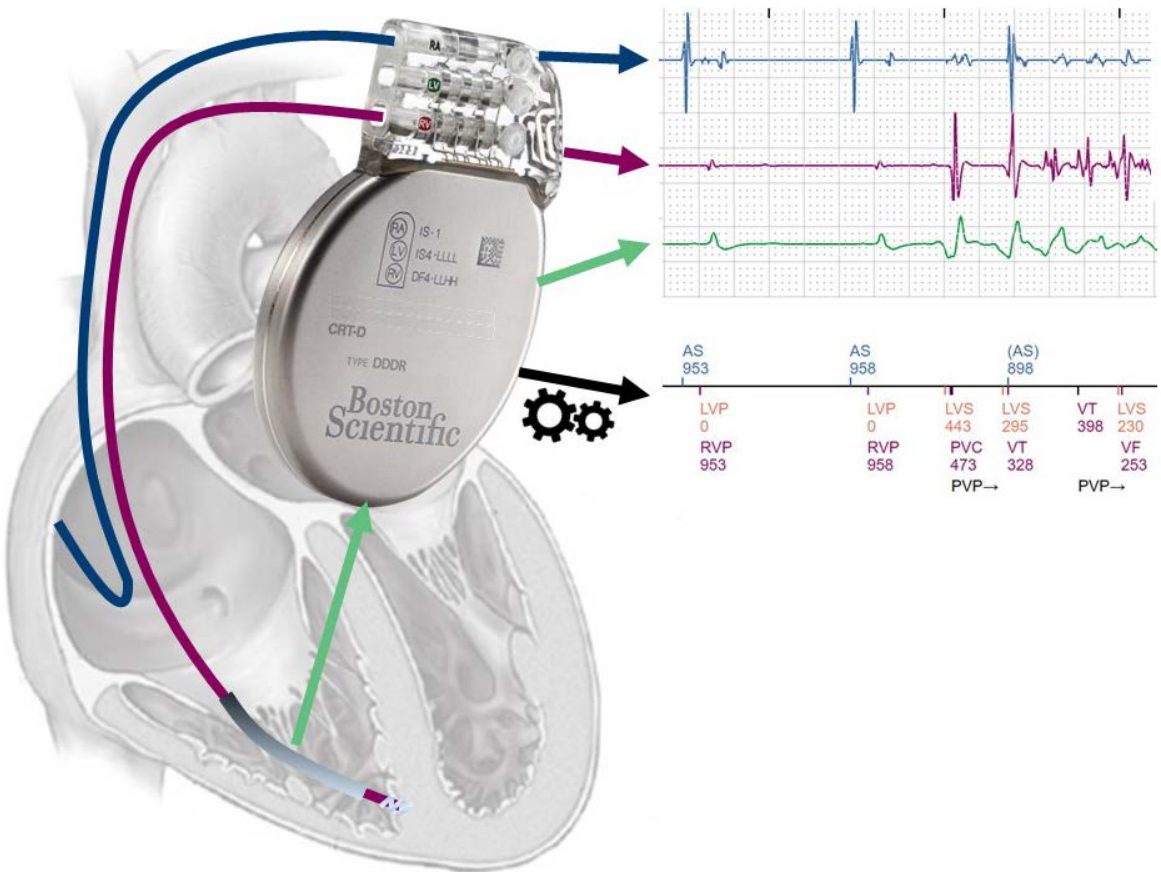
- at the top of the first page of the PDF transmitted to the LATITUDE telemonitoring site you will find various pieces of information: patient's surname, first name, date of birth , implantation center, remote monitoring center, device model and serial number, date of last face-to-face interrogation and date of last telemedicine transmission; the tracings in this book have all been anonymized; the ventricular tachy mode is set to «monitoring + treatment», which means that the full range of detection and treatment options is activated.
- each recorded trace is numbered in chronological order (this is episode 42) along with the date and time of occurrence and information pertaining to the atrial and ventricular rate
- the detail tab summarizes the main diagnostic and treatment steps undertaken for this episode; VF Event Onset: ventricular rate (321 beats/minute) and atrial rate (64 beats/minute) are calculated from the average of the 4 ventricular and atrial cycles preceding the V-Epsd marker; during V-Detect : atrial rate (65 beats/minute) and ventricular rate (297 beats/minute) are calculated by averaging the 4 cycles preceding the V-Detect marker; the episode is always detected in the VF zone; in this zone, no discrimination other than rate is used; on the other hand, various parameters are still recorded (stability, V>A frequency, Fib A, correlated Rhythm ID) even if they do not influence the decision to treat the episode; information on the various timers (SRD, ATP Time-ou t) is also displayed; Attempt 1, 41 J V Shock: the first therapy programmed in the VF zone is a 41 Joule shock; the duration of the charge was 9.8 seconds (expected for a maximum-output shock) with a lead impedance of 76 Ohms (expected for a single-coil lead); the shock waveform is biphasic and the nominal initial polarity corresponds to a cathodic shock (for a single-coil lead, the right ventricular coil is the cathode and the defibrillator can is the anode for the first phase, with polarities reversed for the second phase).
- when a trace is analyzed from the programmer, it is possible to modify the scrolling speed (25 mm/s in the first instance); this can be useful for confirming the diagnosis of oversensing of a 50 Hz signal (scroll speed of 100 mm/s reveals a sinusoidal pattern

with 20 ms between signals); calibration is adapted automatically by the device, but can also be modified from the programmer to facilitate manual measurement of the amplitude of the various signals

- for each trace recorded on a dual- or triple-chamber defibrillator, 3 channels are nominally available: the bipolar atrial sensing channel (A), the bipolar ventricular sensing channel (V) and the shock channel (shock) between the distal coil and the can; the signal on the shock channel is similar to an electrocardiographic lead; ; markers and intervals are also available; compared with other manufacturers, Boston Scientific have chosen to provide a great deal of information on the trace, with numerous markers (for this example, atrial, right and left ventricular markers, PVARP prolongation , correlated cycles , etc.).)
- to start recording an arrhythmia, 3 consecutive beats must occur in one of the tachycardia zones; the device then uses a sliding window during which it looks for the occurrence of 8 out of 10 consecutive rapid cycles; the first 3 cycles are included in this window; when this criterion is met, the V-Epsd marker appears on the trace; the duration starts from this marker; for Boston Scientific devices, a specified number of rapid cycles is not programmed for initial detection, but a duration during which the arrhythmia is sustained; an episode is considered sustained if a minimum proportion of 6 rapid cycles out of 10 is maintained throughout the duration; if, until the end of the duration, the 6/10 criterion is met, the device classifies the episode as VT, SVT or VF; when the duration ends, the last ventricular interval is analyzed to understand the dynamics of the arrhythmia: stable arrhythmia, slowing down or accelerating; if the last interval corresponds to the zone whose duration has just ended, therapies can be delivered; the end of an episode is declared after a duration during which the 8/10 redetection criterion is not met (10 seconds after untreated events, ATP treated events or after an aborted shock; 30 seconds after a delivered shock)
- there are three programmable durations: initial duration (independently programmable in VF and VT zones), post-detection duration (when a charge has been diverted or after

an ATP sequence; programmable in the VT zone, fixed at 1 second in the VF zone) and post-shock duration (after a shock has been delivered; programmable in VT zone, fixed at 1 second in VF zone)

- the interval plot provides an overall view of the episode, with a number of characteristic aspects to be aware of (railroad track appearance cases of P wave oversensing , T wave oversensing or double counting of the R wave, cloud of points with very short cycles in the case of lead dysfunction, undersensing with long cycles in the case of a VF episode, etc.).); interval plot analysis is therefore an integral part of reading the various tracings, and should probably be the first step before detailed analysis of the EGM.



This figure shows the 3 available channels with a good-quality color EGM plot and a multitude of markers (lots of information, the plot is sometimes a little busy).

2 Detection and treatment of a VT episode

Patient

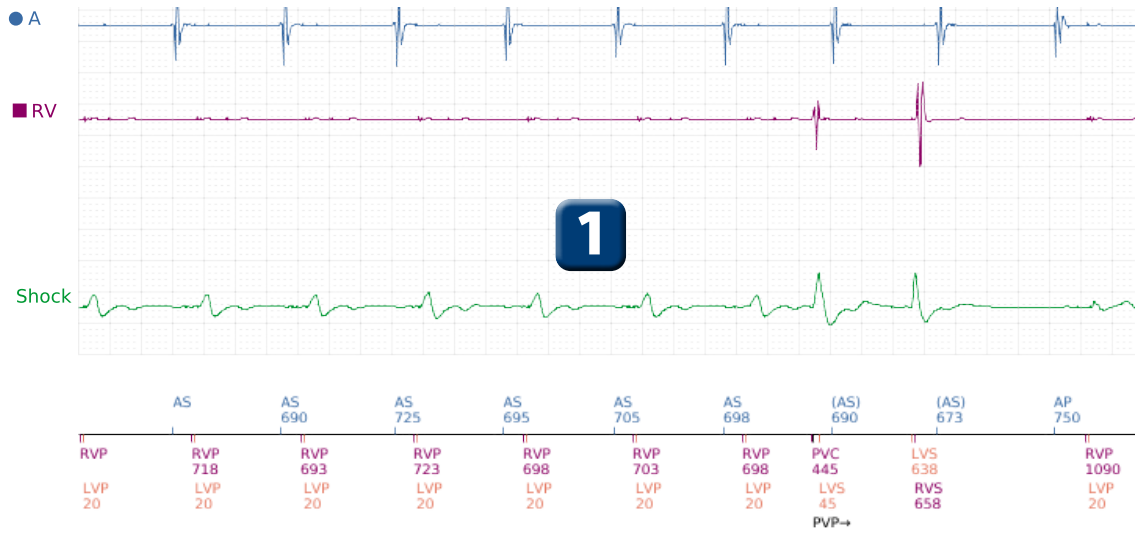
- Female with ischaemic cardiomyopathy; implanted with a Momentum triple-chamber defibrillator

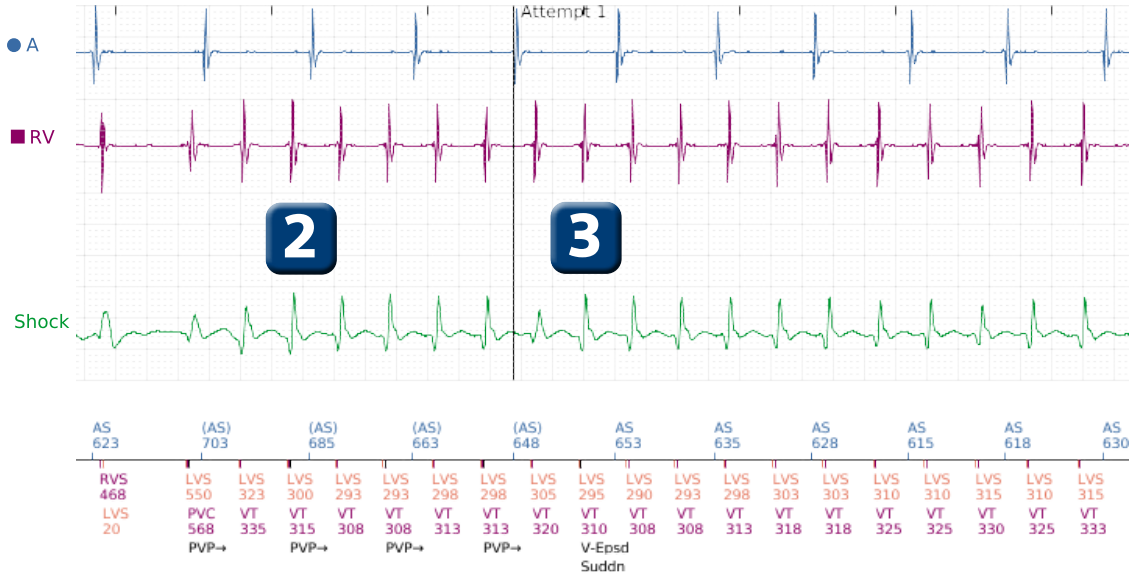
Summary

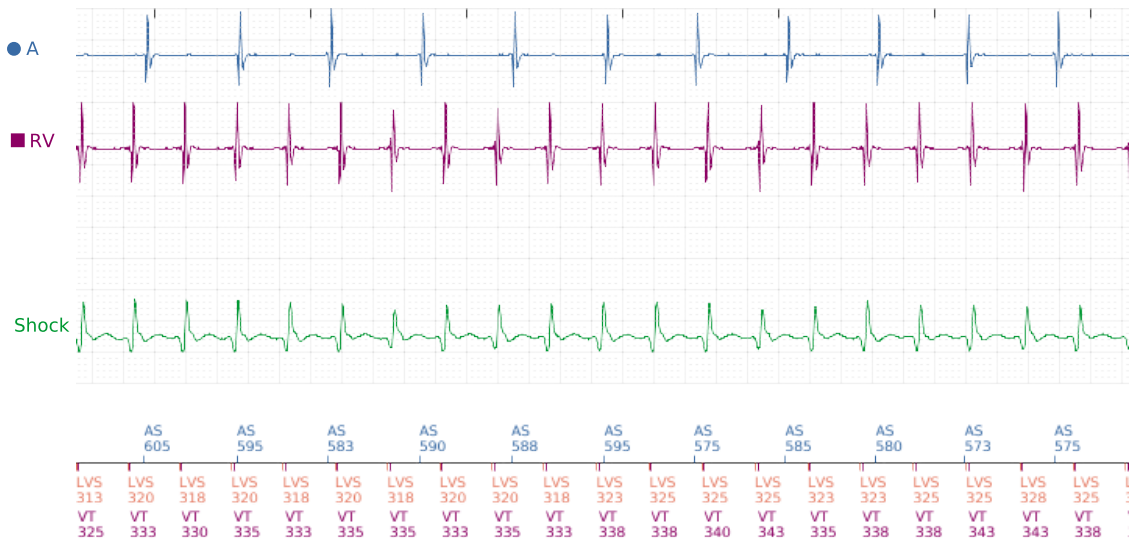
- episode classified in the VT zone
- discrimination criterion V>A: True
- burst of ATP delivered

EGM layout

1. spontaneous rhythm in the atrium and bi-ventricular pacing
2. onset of ventricular tachycardia (regular, monomorphic with atrioventricular dissociation)
3. VT episode (V-Epsd) after 8 cycles in VT zone (criterion 8/10 verified); start of initial VT zone duration (12 seconds)
4. diagnosis of sustained VT (V-Detect) at end of duration; discrimination criterion V>A verified
5. burst of 8 impulses at a fixed rate; biventricular pacing
6. effective burst and arrhythmia termination


A
RV
Shock
1
AS AS AS AS AS (AS) (AS) AP
690 725 695 705 698 690 673 750
RVP RVP RVP RVP RVP RVP RVP PVC RVP
718 693 723 698 703 698 445 1090
LVP LVP LVP LVP LVP LVP LVP LVS LVP
20 20 20 20 20 20 20 45 20
LVS
638
RVS
658
PVP→


Attempt 1
A
RV
Shock
2
3
AS (AS) (AS) (AS) (AS) AS AS AS AS AS AS
623 703 685 663 648 653 635 628 615 618 630
RVS
468
LVS
20
LVS 550 PVC 568 PVP→
LVS 323 VT 335
LVS 300 VT 315 PVP→
LVS 293 VT 308
LVS 293 VT 308 PVP→
LVS 298 VT 313
LVS 298 VT 313 PVP→
LVS 305 VT 320
LVS 295 VT 310 V-Epsd
LVS 290 VT 308 Suddn
LVS 293 VT 308
LVS 298 VT 313
LVS 303 VT 318
LVS 303 VT 318
LVS 310 VT 325
LVS 310 VT 325
LVS 315 VT 330
LVS 310 VT 325
LVS 315 VT 333


A
RV
Shock
AS AS AS AS AS AS AS AS AS AS AS
605 595 583 590 588 595 575 585 580 573 575
LVS 313 VT 325
LVS 320 VT 333
LVS 318 VT 330
LVS 320 VT 335
LVS 318 VT 333
LVS 320 VT 335
LVS 318 VT 335
LVS 320 VT 333
LVS 320 VT 335
LVS 318 VT 333
LVS 323 VT 338
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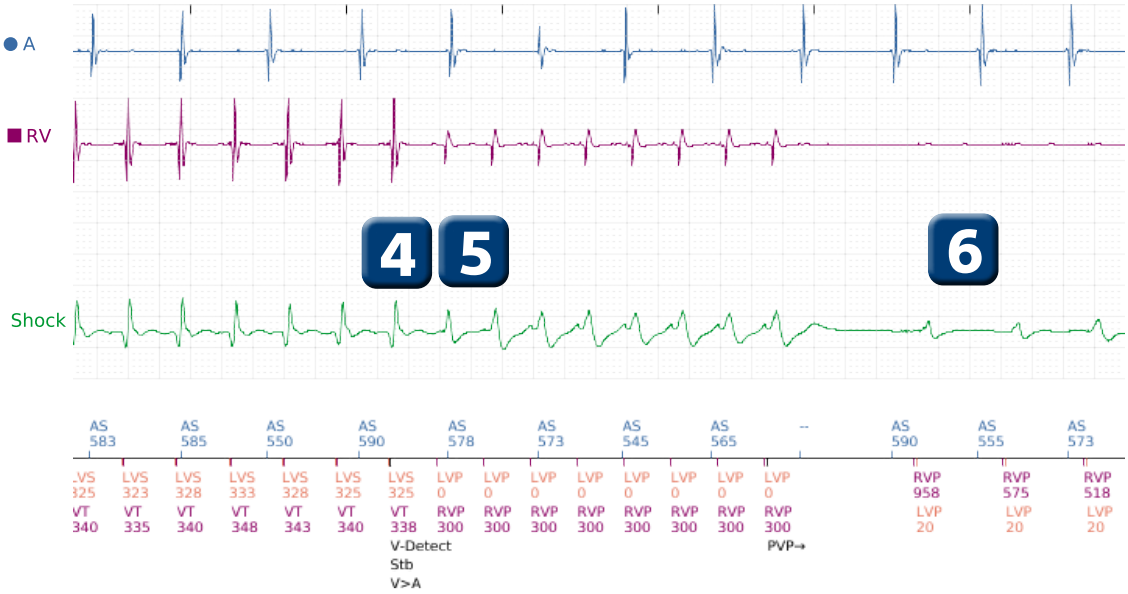
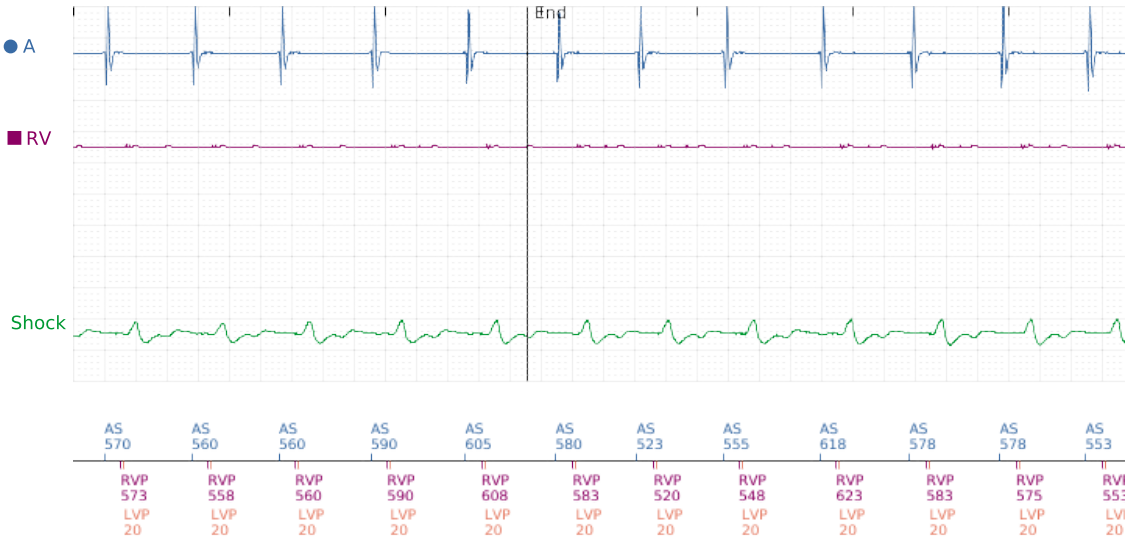
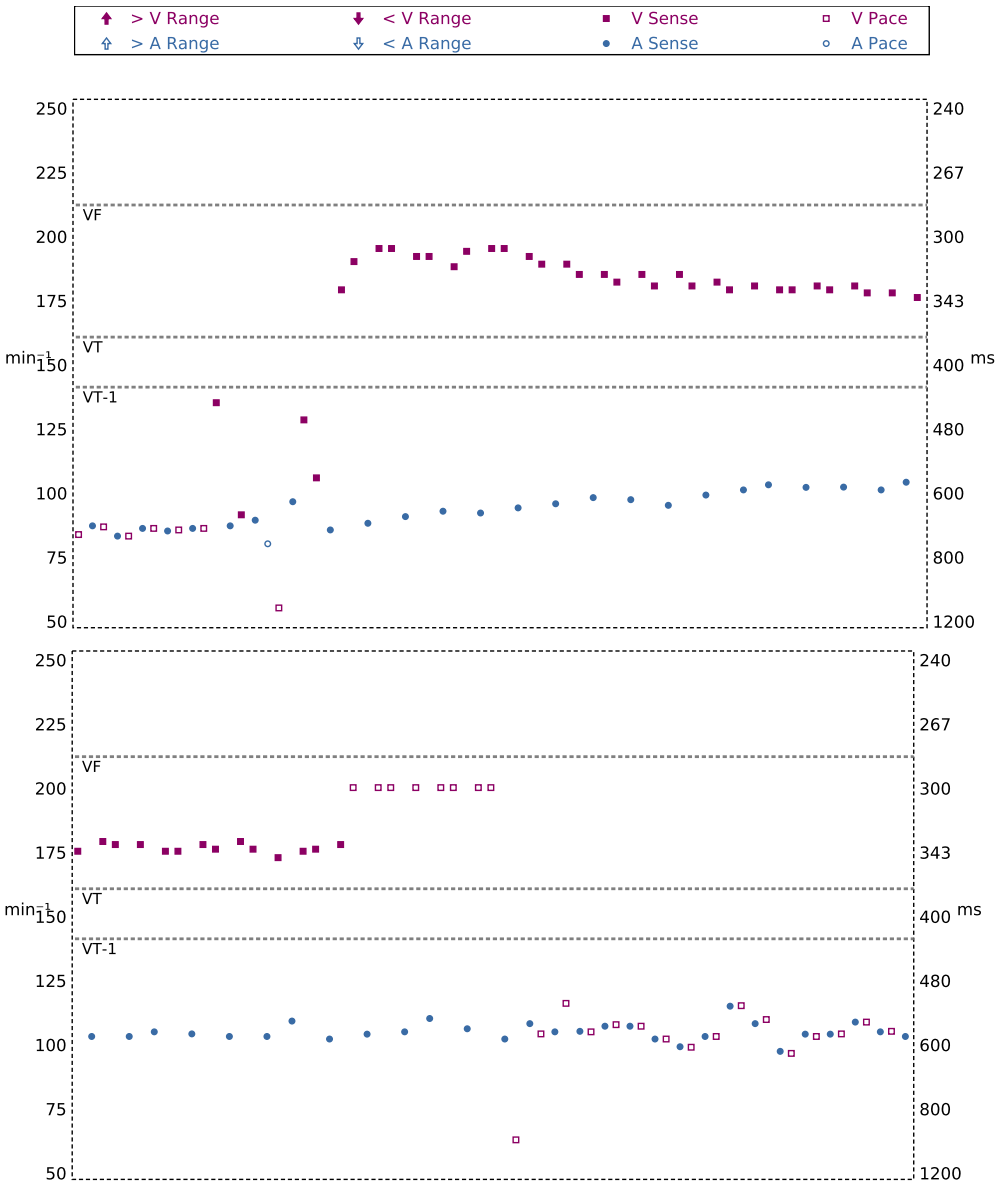
LVS 325 VT 338
LVS 325 VT 343
LVS 328 VT 343
LVS 325 VT 338


A
RV
4
5
6
Shock
AS 583 AS 585 AS 550 AS 590 AS 578 AS 573 AS 545 AS 565 -- AS 590 AS 555 AS 573
LVS 325 LVS 323 LVS 328 LVS 333 LVS 328 LVS 325 LVS 325 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0
VT 340 VT 335 VT 340 VT 348 VT 343 VT 340 VT 338 RVP 300 RVP 300 RVP 300 RVP 300 RVP 300 RVP 300 RVP 300 RVP 300
V-Detect
Stb
V>A
PVP→
RVP 958 RVP 575 RVP 518
LVP 20 LVP 20 LVP 20


End
A
RV
Shock
AS 570 AS 560 AS 560 AS 590 AS 605 AS 580 AS 523 AS 555 AS 618 AS 578 AS 578 AS 553
RVP 573 RVP 558 RVP 560 RVP 590 RVP 608 RVP 583 RVP 520 RVP 548 RVP 623 RVP 583 RVP 575
LVP 20 LVP 20 LVP 20 LVP 20 LVP 20 LVP 20 LVP 20 LVP 20 LVP 20 LVP 20 LVP 20 LVP 20

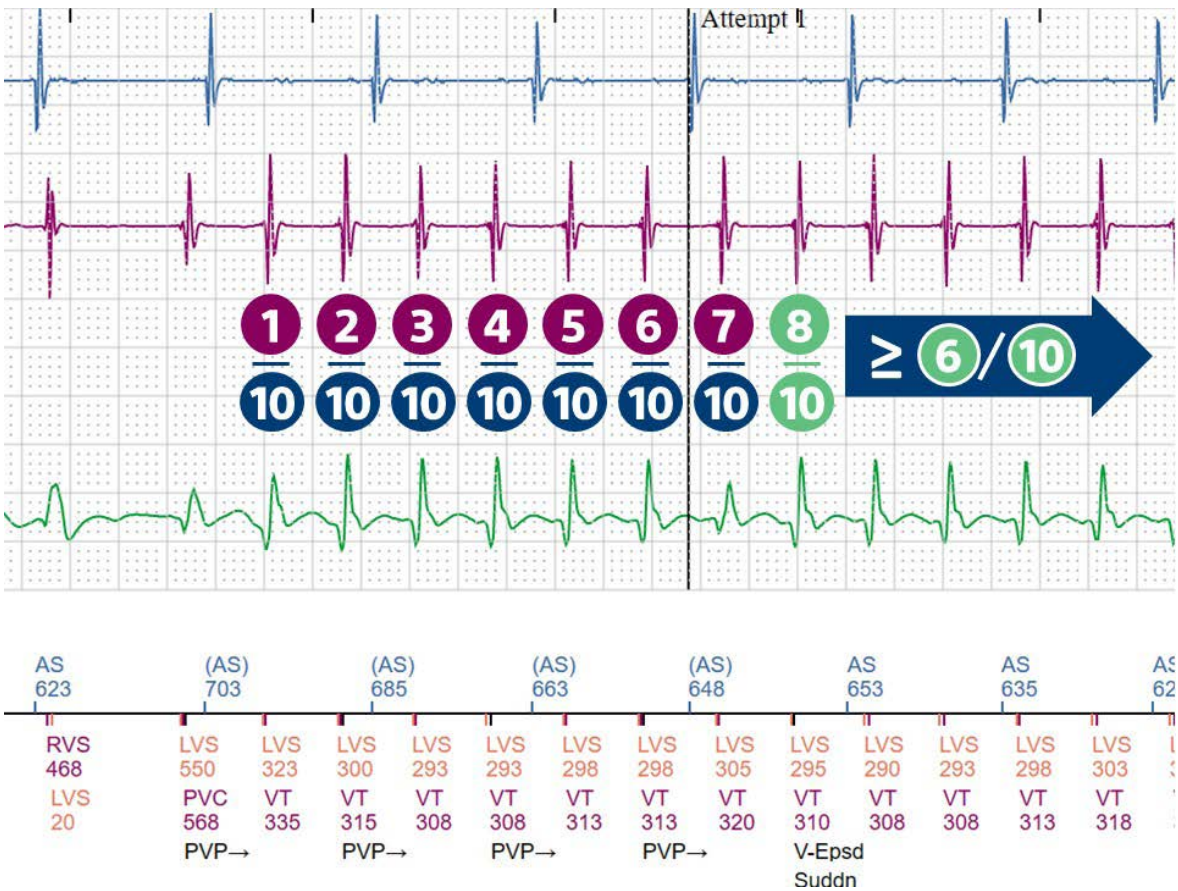

> V Range
< V Range
V Sense
V Pace
> A Range
< A Range
A Sense
A Pace
250
225
200
175
150
125
100
75
50
min⁻¹
VF
VT
VT-1
240
267
300
343
400
480
600
800
1200
ms

Points to remember

- these first 2 tracings (termination of a disorganized polymorphic arrhythmia by a shock, and termination of an organized ventricular arrhythmia by anti-tachycardia pacing) illustrate the basics of how the Boston ScientificTM defibrillator detection counters work.
- it is possible to program 1 (VF), 2 (VF + VT) or 3 (VF + VT + VT-1) detection zones; counter operation is identical for all 3 zones; initial detection requires a minimum ratio of 8 rapid cycles out of 10; this ratio then decreases to 6 out of 10 during the duration of detection; during post-charge confirmation, for a shock to be delivered, a ratio of 2 rapid cycles out of 3 is required; during re-detection or post-shock, identical counters apply (8/10 then 6/10); therefore during an episode, the same probabilistic counters (X/Y rapid cycles) are applied in both VT and VF zones.
- the first tracing showed an episode of VF; probabilistic counters seem to be most suitable for this type of arrhythmia; ventricular fibrillation is by definition rapid, disorganized and, chaotic, with ventricular signals of low and/or variable amplitude; all these characteristics increase the risk of undersensing due to low amplitude signals below the sensitivity threshold (nominal value of 0.6 mV); the high beat-to-beat variability of the amplitude may fool the sensing circuit, as the defibrillator uses a sensitivity level that adapts to the amplitude of the preceding signal; the first counter requires a minimum of 80% rapid cycles (criterion 8/10); this 80% ratio between fast and slow cycles has been chosen to achieve an optimum balance between correct detection of ventricular fibrillation (requiring tolerance of a certain number of pseudo long cycles generated by undersensing) and the need to avoid filling counters in the presence of T wave, P wave or R wave oversensing (frequently associated with a ratio of 50% short cycles), or sensing of frequent ventricular extrasystoles; this 80% ratio is not programmable, nor is the number of cycles (8 out of 10); once this first stage of detection has been achieved, the duration in the VF zone begins, with a lower requirement of 60% rapid cycles; the device considers that if the first stage criterion has been met (8/10), the

probability of a true arrhythmia is high, and the priority is then to avoid being fooled by possible undersensing (hence a lower number of rapid cycles are required).

- the second tracing shows a regular, monomorphic ventricular tachycardia detected in the VT zone; for this type of arrhythmia, the operation of a probabilistic counter is also effective since sensing is generally correct and 100% of cycles are correctly sensed



This figure shows the different counters: initial detection of 8/10 with marker (V-Epsd), then initial duration with rolling window and 6/10 counter.

3 Non-sustained ventricular tachycardia

Patient

- male with dilated cardiomyopathy and numerous episodes of non-sustained VT; implanted with a Resonate triple-chamber defibrillator

Summary

- episode classified as non-sustained VT

EGM layout

1 spontaneous rhythm in the atrium and biventricular pacing

2 onset of ventricular tachycardia (regular, monomorphic with atrioventricular dissociation)

3 alternation between a cycle classified in the VT zone and a cycle classified as an extrasystole; to trigger the search for the 8/10 criterion, 3 consecutive cycles in a tachycardia zone are required; this first VT cycle (followed by a cycle sensed outside a tachycardia zone) therefore does not count towards the 8/10 criterion.

4 third consecutive cycle in the VT zone (3 consecutive cycles criterion met)

5 VT episode (V-Epsd) after 8 cycles in VT zone (including 3 consecutive cycles); start of initial VT zone duration (programmed to 12 seconds)

6 spontaneous termination

7 after 5 cycles outside the tachycardia zone, criterion 6/10 is no longer met

8 end-of-episode marker (10 seconds after criterion 6/10 is no longer met)

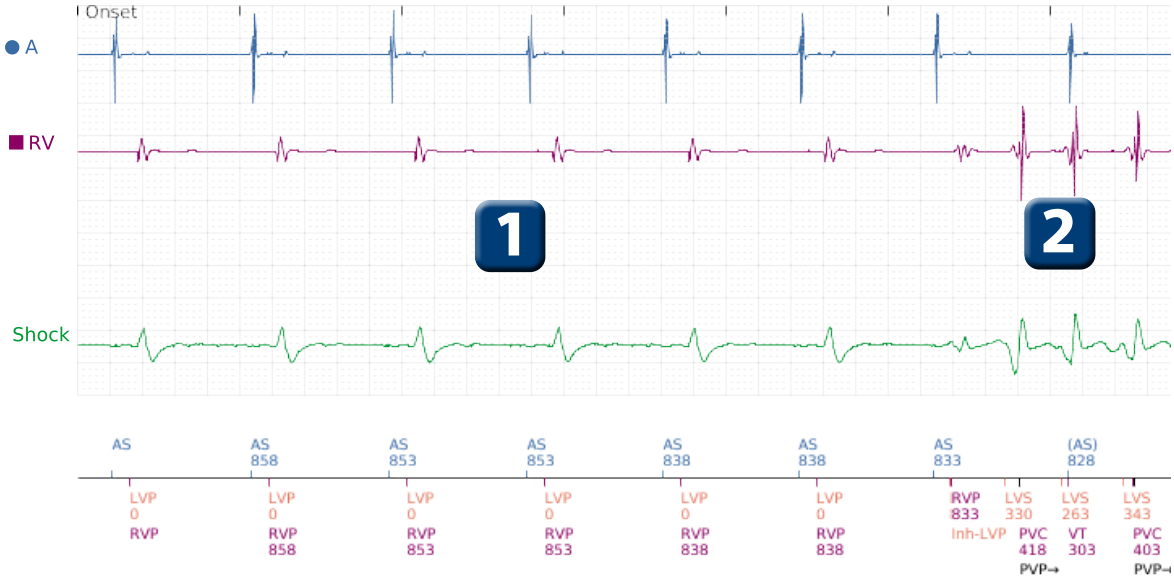
V-1: 18 Mar 2022 14:13, NonSustV, A Rate: 76 min^{-1}, V Rate: 199 min^{-1}

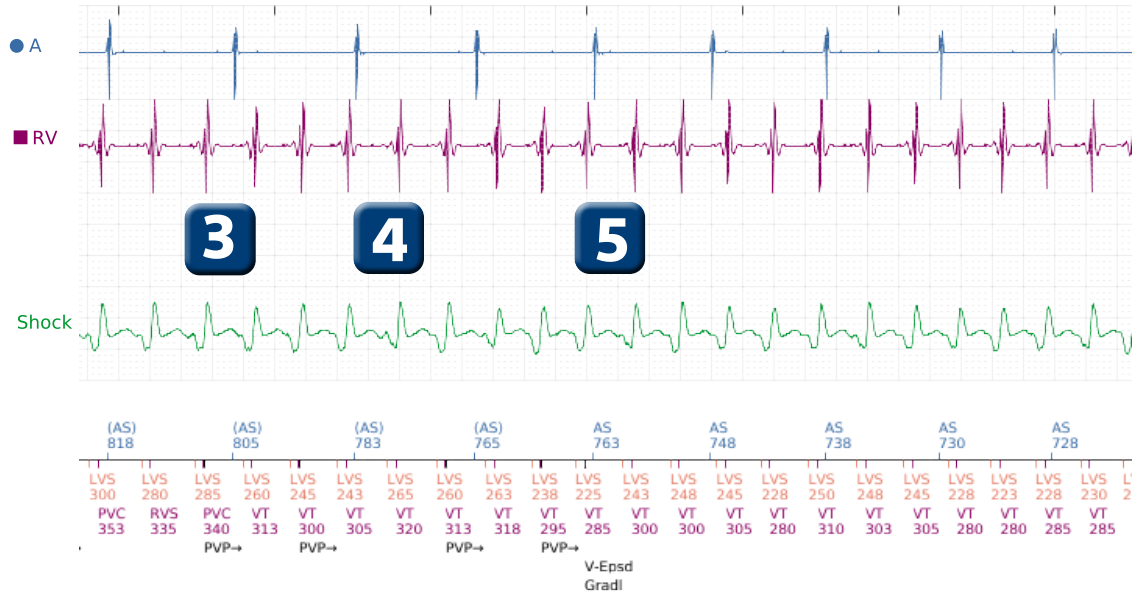
Detail

NonSustV Event Onset

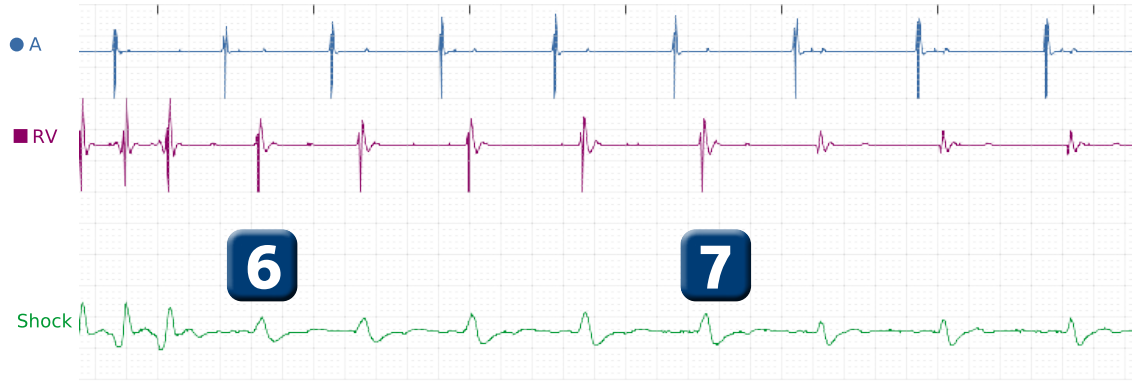
Avg A Rate	76 min^{-1}
Avg V Rate	199 min^{-1}
Detection	Onset/Stability
Onset	Percent
Template	N/R
Event Ended	00:00:19

EGM displayed at 25mm per second

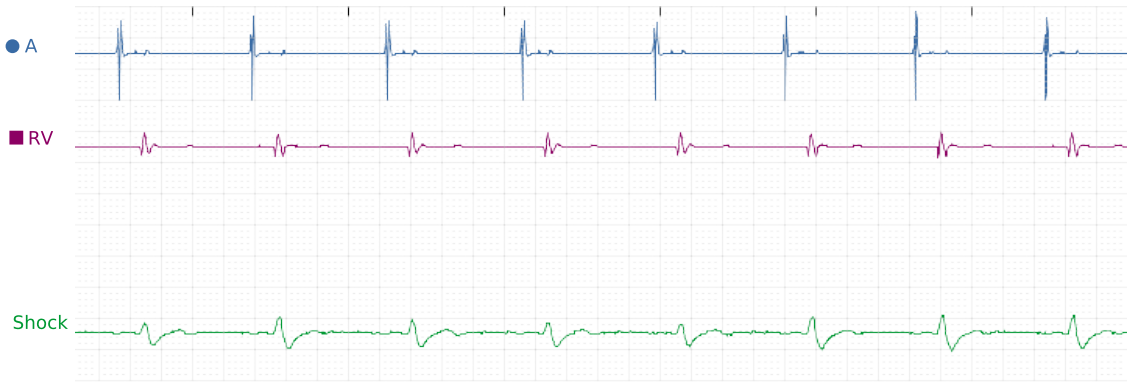




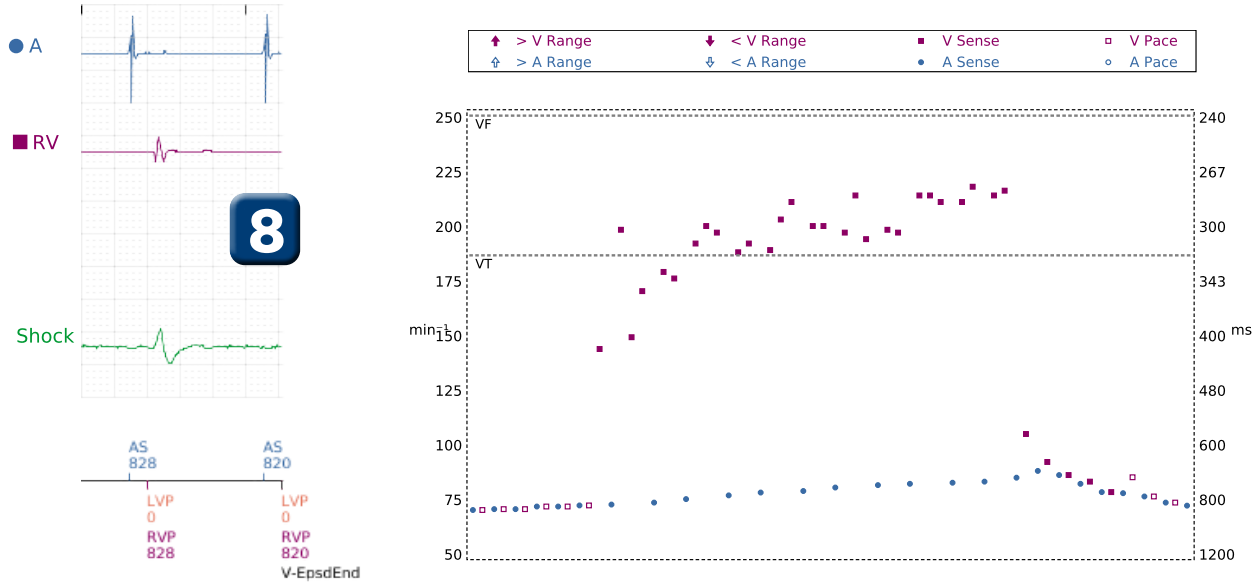
	(AS) 818		(AS) 805		(AS) 783		(AS) 765		AS 763		AS 748		AS 738		AS 730		AS 728	
	LVS 300	LVS 280	LVS 285	LVS 260	LVS 245	LVS 243	LVS 265	LVS 260	LVS 263	LVS 238	LVS 225	LVS 243	LVS 248	LVS 245	LVS 228	LVS 250	LVS 248	LVS 245	LVS 228	LVS 223	LVS 228	LVS 230
	PVC 353	RVS 335	PVC 340	VT 313	VT 300	VT 305	VT 320	VT 313	VT 318	VT 295	VT 285	VT 300	VT 300	VT 305	VT 280	VT 310	VT 303	VT 305	VT 280	VT 280	VT 285	VT 285
			PVP→		PVP→			PVP→		PVP→	V-Epsd Gradl											



AS 725	AS 708	AS 683	AS 700	AS 730	AS 768	AS 773	AS 788	AS 818
VS 18 LVS 223 LVS 218	RVS 573	RVS 653	RVS 698	RVS 725	RVS 768	LVP 0	LVP 0	LVP 0
VT 275 VT 280 VT 278	LVS 130	LVS 133	LVS 133	LVS 118	LVS 118 PVP→	RVP 710	RVP 788	RVP 818



AS 835	AS 858	AS 863	AS 870	AS 850	AS 838	AS 835	AS 838
LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0
RVP 835	RVP 858	RVP 863	RVP 870	RVP 850	RVP 838	RVP 835	RVP 838



Points to remember

- this patient had multiple episodes of non-sustained VT prior to implantation; the priority during programming is to avoid any therapy on these spontaneously resolving arrhythmia episodes; 2 options may be preferred: programming lower limits of tachycardia zones above the rate of clinical VT, or programming initial durations long enough to promote spontaneous termination
- this trace illustrates one of the major developments in the programming of implantable defibrillators, namely the programming of longer initial durations; one of the main programming objectives of the first implanted devices was to treat the various arrhythmias detected (VT or VF) without delay; there are several explanations for this initial strategy and tendency towards rapid treatment with a device-based shock: 1. most initial patients received implants for secondary prevention, 2. there was concern surrounding the risk of VF undersensing , 3. various studies had shown a positive correlation between monophasic shock defibrillation threshold and the duration of the episode; similarly, documentation of inappropriate therapies was limited since the very first devices did not record tracings
- various technological advances, an increase in the proportion of patients implanted for primary prevention, widely publicized problems of inappropriate therapies due to

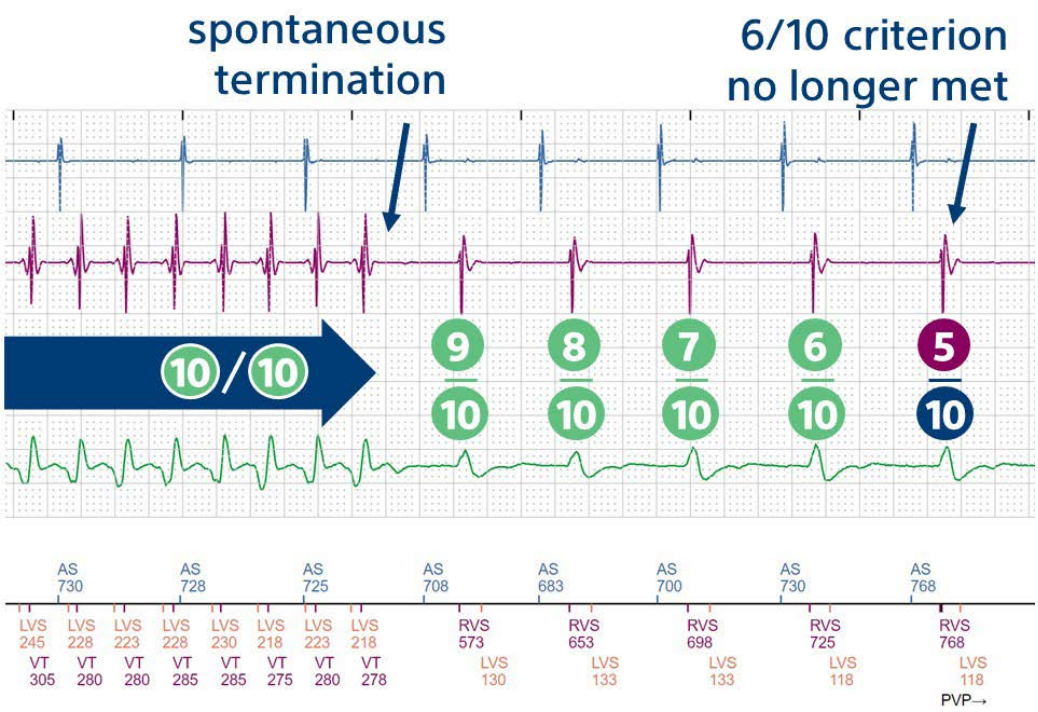
lead dysfunction, and the results of various large-scale studies have all contributed to a considerable change in the way modern defibrillators are programmed: the PREPARE study was the first to show that longer detection times could reduce the number of shocks delivered without increasing complications (syncope, sudden death, etc.); the Multicenter Automatic Defibrillator Implantation Trial: Reduce Inappropriate Therapy (MADIT-RIT) showed the positive impact of programming a single VF zone (> 200 beats/minute) or implementing delayed therapy (1 minute for the zone between 170 and 200 beats/minute and 12 seconds between 200 and 250 beats/minute) compared to conventional programming; other studies and meta-analyses have confirmed benefits in terms of reducing appropriate or inappropriate therapy and reducing mortality, suggesting a definite benefit to such programming.

- the nominal programming suggested by manufacturers has gradually evolved; in 2015 and again in 2019, consensus guidelines for the programming of implantable defibrillators reiterated the need for default programming of high detection zones with longer initial durations
- for a patient implanted with a Boston ScientificTM defibrillator for primary prevention, 2 programming options can be selected: 1) delayed therapies: a VT zone from 185 beats/minute with an initial duration of 12 seconds and a VF zone from 250 beats/minute with an initial duration of 5 seconds; 2) therapies with a higher detection zone: a single VF zone from 200 beats/minute with an initial duration of 2.5 seconds.
- for a patient implanted with a Boston ScientificTM defibrillator for secondary prevention, it is recommended to add a VT zone (VT-1 if delayed therapies are chosen) at a rate 10 to 20 beats slower than the clinical tachycardia, with an initial duration of at least 12 seconds.
- as this patient's clinical VT was relatively rapid (oscillating around 200 beats/minute), the longer initial duration option (12 seconds for the VT zone, 5 seconds in the VF zone) was preferred
- this trace also provides details of how detection works; initially, 3 consecutive fast ventricular cycles (VT-1, VT or VF) must be detected for the device to search for the

existence of an episode (these 3 consecutive cycles are then included in the search for criterion 8/10); throughout the duration, criterion 6/10 rapid cycles must be maintained; on this trace, the arrhythmia terminates and after 5 slow cycles, the duration is interrupted; 10 seconds later, the end-of-episode marker appears (non-programmable criterion; criterion 8/10 not verified 10 seconds after an untreated or ATP-treated episode, 30 seconds after a shock).

Detection	In patients with no VT history *Option 1* – delayed therapy VF: 8 of 10 intervals plus 5-second duration*, 250bpm* VT: 8 of 10 intervals plus 12-second duration*, 185bpm* VT-1: Monitor, at user discretion *Option 2* – high-rate therapy VF: 8 of 10 intervals plus 2.5-second duration*, 200bpm* VT-1: Monitor, at user discretion In patients where VT cycle length is known VF: 5-second duration*, 250bpm* VT: 12-second duration*, 185bpm* or 10–20bpm < VT rate VT-1: Monitor Zone or Therapy at ≥12-second duration*, 10–20bpm < VT rate

Extract of the 2019 HRS/EHRA recommendations with QR code (to PDF)



This figure shows the spontaneous termination and the point at which the 6/10 criterion is no longer met.

4 Change of detection zone

Patient

- male with ischemic cardiomyopathy; implanted with Momentum triple-chamber defibrillator

Summary

- episode initially classified in the VT zone then in the VF zone
- a burst of ATP delivered followed by a 41 Joule shock

EGM layout

1 spontaneous rhythm in the atrium and biventricular pacing

2 onset of ventricular tachycardia (regular, monomorphic, with atrioventricular dissociation)

3 cycles initially classified in the VT zone

4 cycles classified as VF

5 V-epsd marker for VT zone (5 cycles in VT zone + 3 cycles in VF zone); start of initial duration for VT zone (2.5 seconds)

6 after 8 cycles in the VF zone, criterion 8/10 verified for the VF zone; start of initial duration of VF zone

7 end of duration for the VT zone (V-Dur) but criterion 6/10 is still valid for the VF zone; VT zone therapies are therefore not delivered.

8 after 5 consecutive cycles classified as VT, the 6/10 criterion is no longer met for the VF zone; the first VT zone therapy can be delivered

9 burst

10 ineffective burst and ongoing arrhythmia

11 on this cycle, the 8/10 criterion for redetection is fulfilled for the VT zone (1 VT cycle and 7 VF cycles); start of post-redetection duration for the VT zone (1 second).

12 on this cycle, the 8/10 redetection criterion is validated for the VF zone (8 VF cycles); start of post-redetection duration for the VF zone (1 second).

13 end of post-redetection duration for VT zone (V-Dur) but VF zone duration is still active

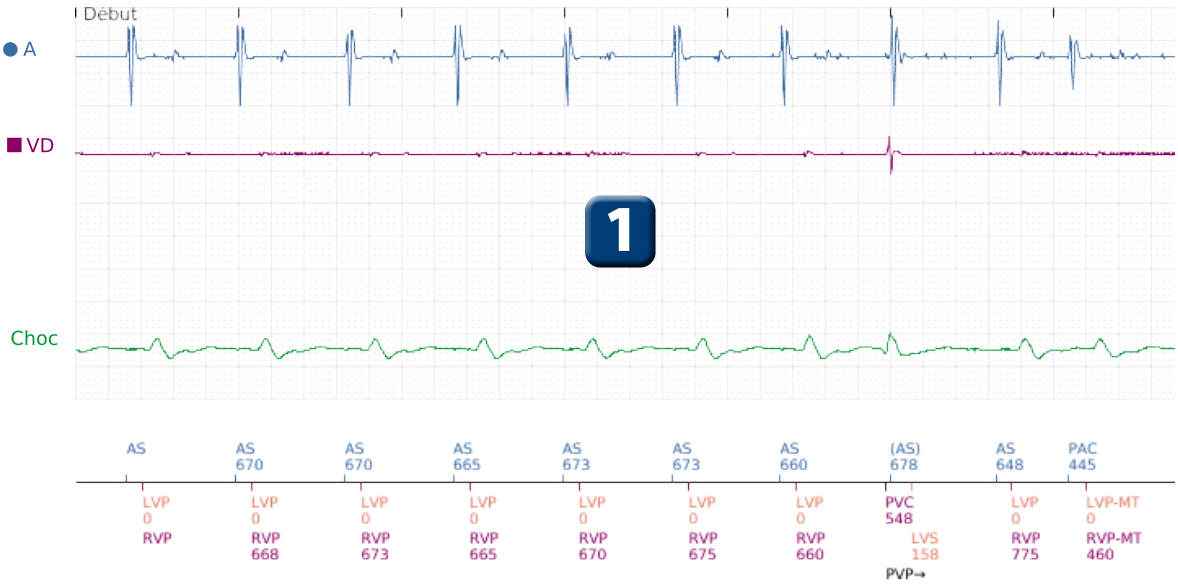
14 end of VF zone duration (switches to VF zone detection with therapies corresponding to this zone)

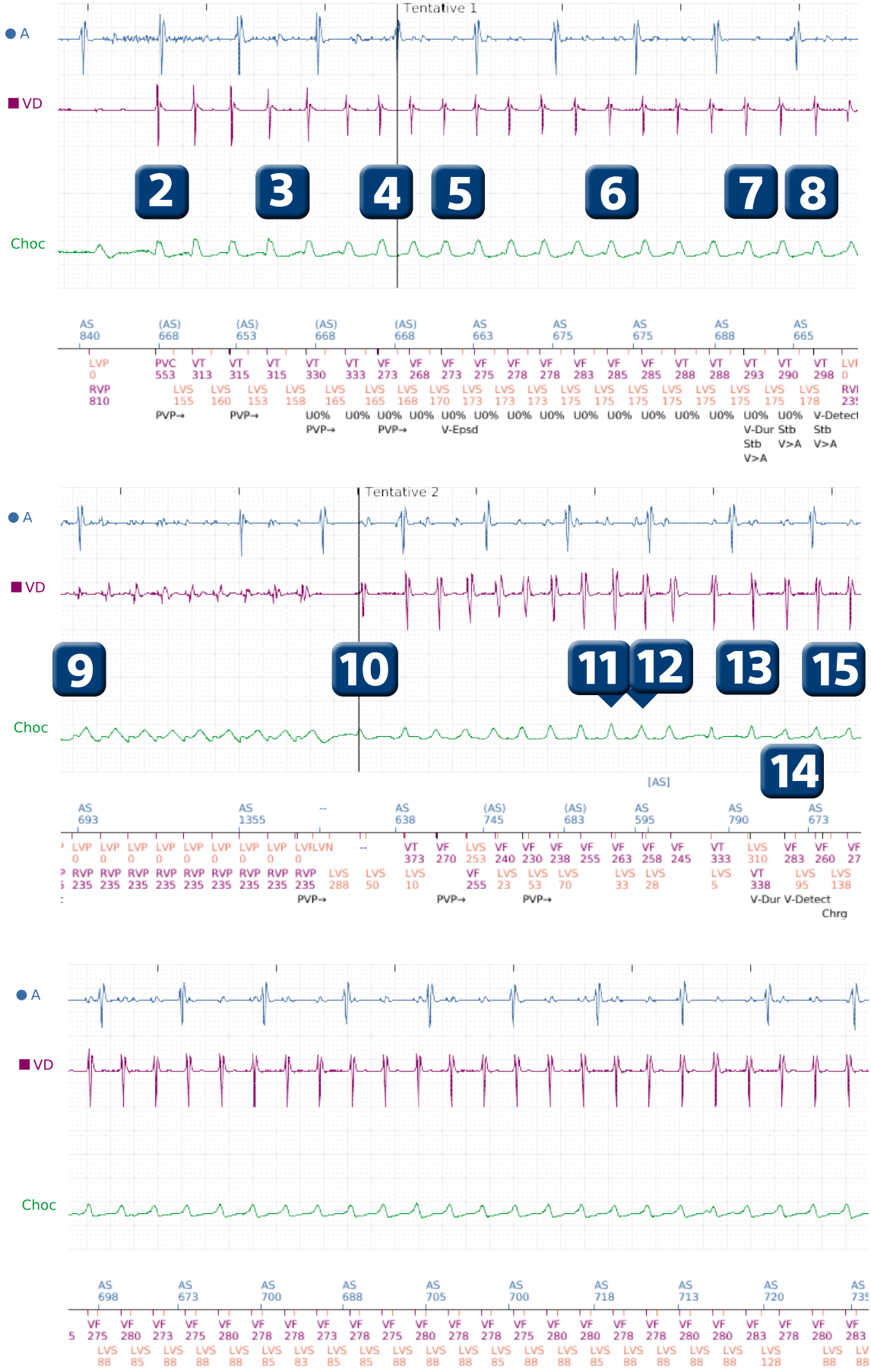
15 start of capacitor charging

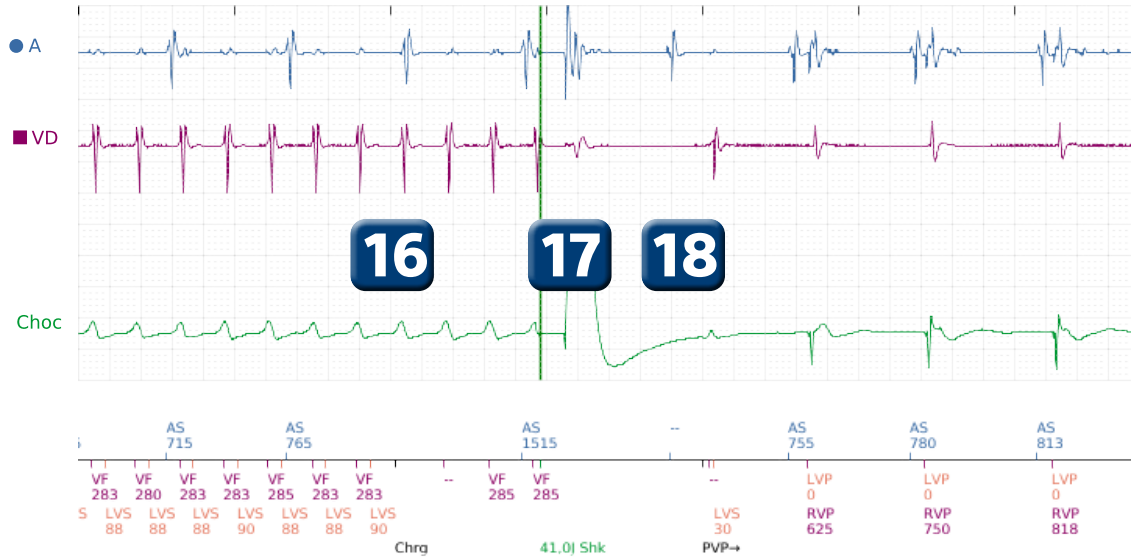
16 end of charge and start of diversion window

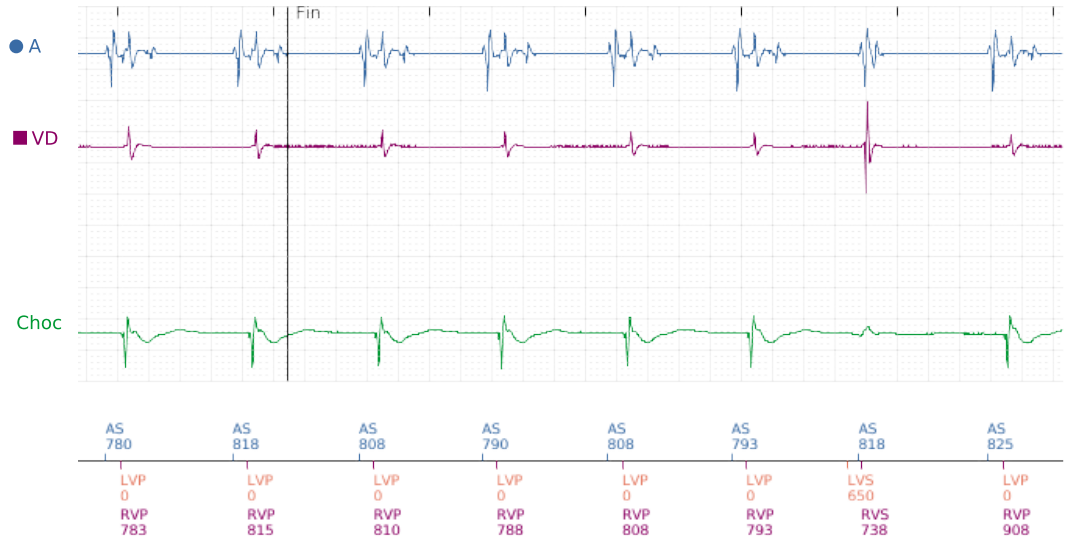
17 shock delivered on the second rapid cycle

18 effective shock




Tentative 1
A
VD
Choc
2
3
4
5
6
7
8
Tentative 2
9
10
11
12
13
14
15
[AS]
V-Epsd
V-Dur
V-Detect
Chrg


A
VD
Choc
16
17
18
AS 715
AS 765
AS 1515
AS 755
AS 780
AS 813
VF 283
VF 280
VF 283
VF 283
VF 285
VF 283
VF 283
VF 285
VF 285
LVP 0
LVP 0
LVP 0
LVS 88
LVS 88
LVS 88
LVS 90
LVS 88
LVS 88
LVS 90
LVS 30
RVP 625
RVP 750
RVP 818
Chrg
41,0J Shk
PVP→


Fin
A
VD
Choc
AS 780
AS 818
AS 808
AS 790
AS 808
AS 793
AS 818
AS 825
LVP 0
LVP 0
LVP 0
LVP 0
LVP 0
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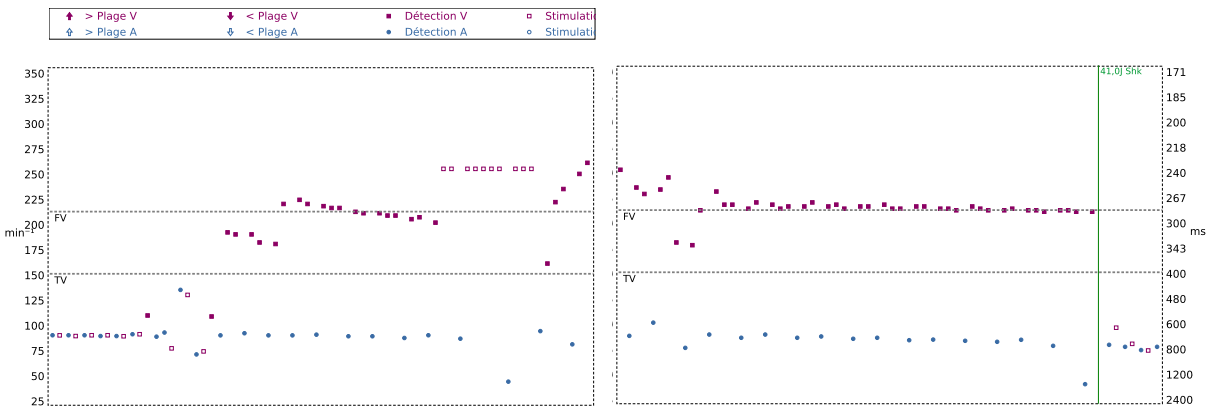
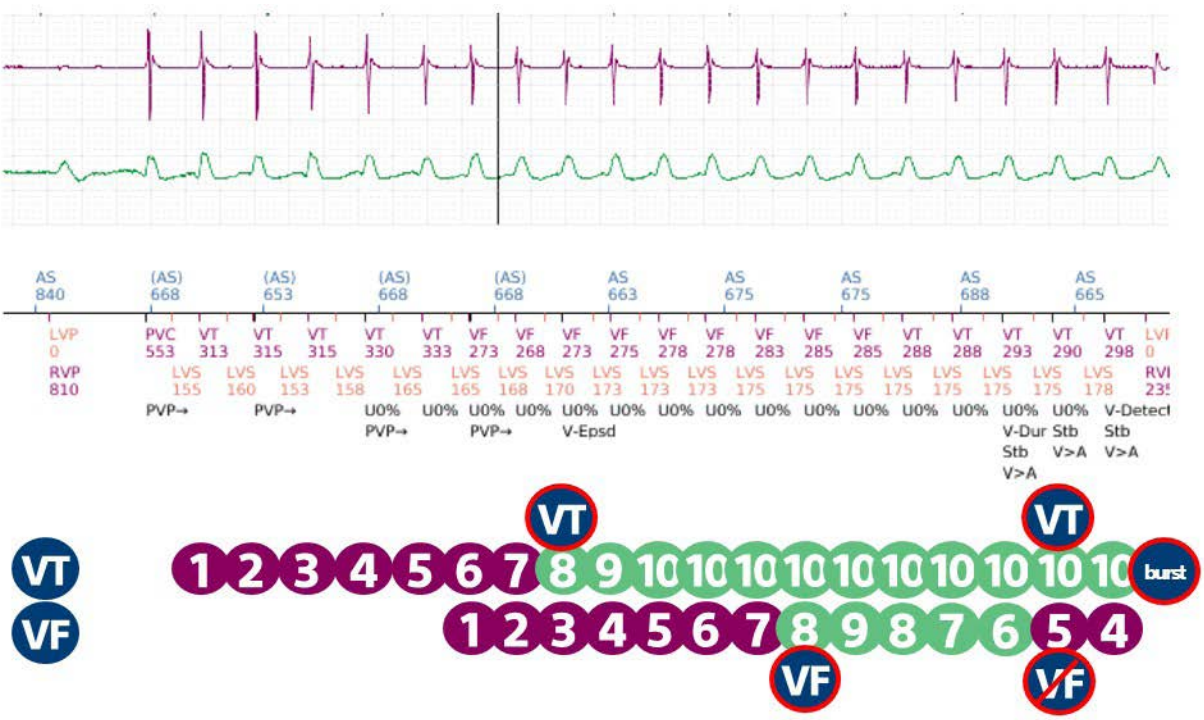
RVP 788
RVP 808
RVP 793
RVS 738
RVP 908


> Plage V
< Plage V
Détection V
> Plage A
< Plage A
Détection A
min
FV
TV
ms
41,0J Shk

Points to remember

- in a Boston Scientific defibrillator, 1, 2 or 3 detection zones can be programmed; the rate thresholds of adjacent zones must differ by at least 20 beats/minute ; in a double- or triple-chamber defibrillator, the rate threshold of the VT zones must be at least 5 beats/minute higher than the maximal tracking rate (MT) and the sensor indicated rate (FMC); in a single-chamber defibrillator, the rate threshold of the VT zones must be at least 15 beats/minute higher than the lower rate limit (Fmin).
- if several detection zones are programmed, each zone has its own detection window; a cycle in a faster zone (VF for VT, for example) increments its zone counter (VF) as well as that of the slower zone (VT and VT-1); when the 8 fast cycles/10 criterion is met for one of the zones, the initial detection criterion is met
- different durations can be programmed for each detection zone; the duration of each zone ends independently of the others; the duration of the faster zones must be shorter than (or equal to) those of the slower zones; if criterion 8/10 is met for the VT zone first and then for the VF zone, the 2 durations continue in parallel; if the VT zone duration ends while the VF zone duration is in progress (criterion 6/10 met in the VF zone), no therapy is delivered before the end of the VF zone duration; if criterion 6/10 is no longer met for the VF zone, as in this example, the VT zone therapies are delivered.
- if the device diagnoses a VT episode and delivers an ATP sequence, and if criterion 8/10 is then verified for the VF zone (acceleration of arrhythmia), the redetection time (1 second in VF zone) of the VF zone and not the initial time (often programmed at a longer interval) is applied so as to not delay the onset of therapies



This figure shows that the 8/10 criterion for the VT zone is initially met, then this criterion is also met for the VF zone; at the end of the VT zone duration, the VF zone duration is still active and VT zone therapies are not delivered; the 6/10 criterion for the VF zone is then no longer fulfilled and the burst (first programmed VT zone

5 Spontaneous termination and shock diversion

Patient 1

- male with ischemic cardiomyopathy implanted with a Resonate single-chamber defibrillator

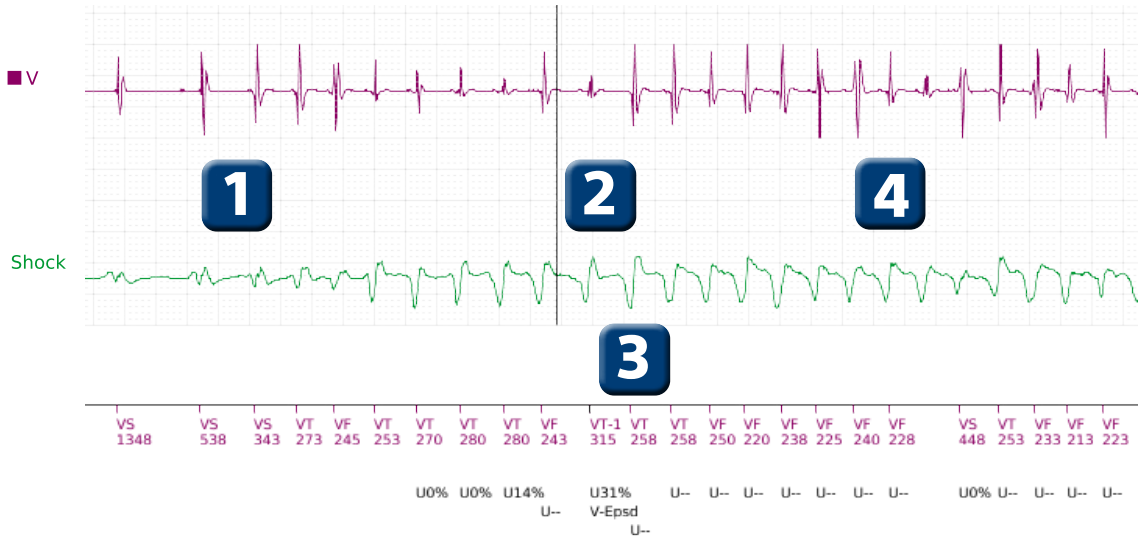
Summary

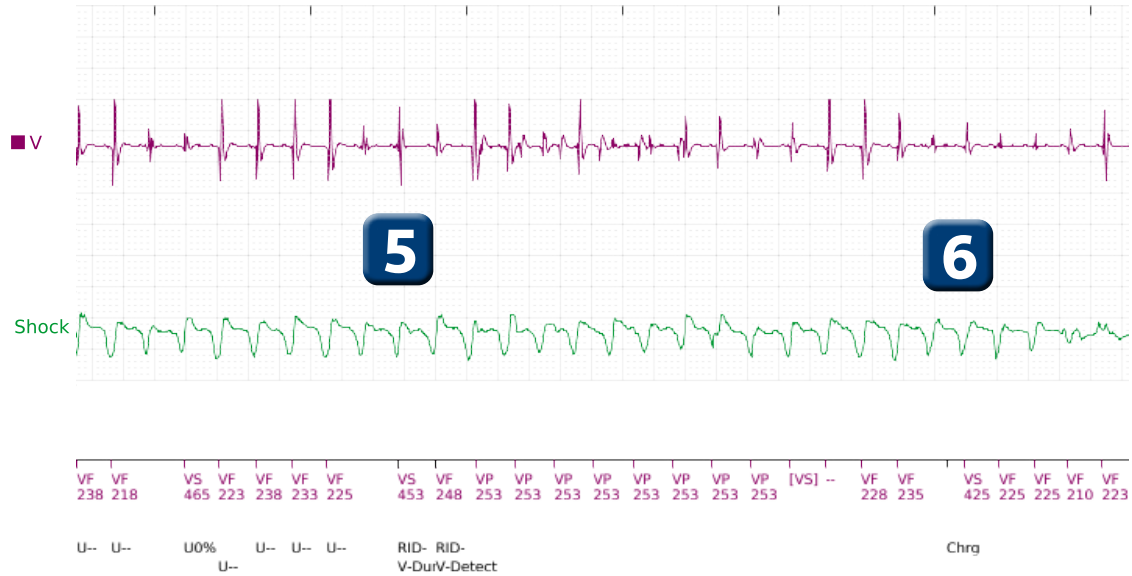
- episode classified in the VF zone
- ATP in the VF zone
- diverted shock

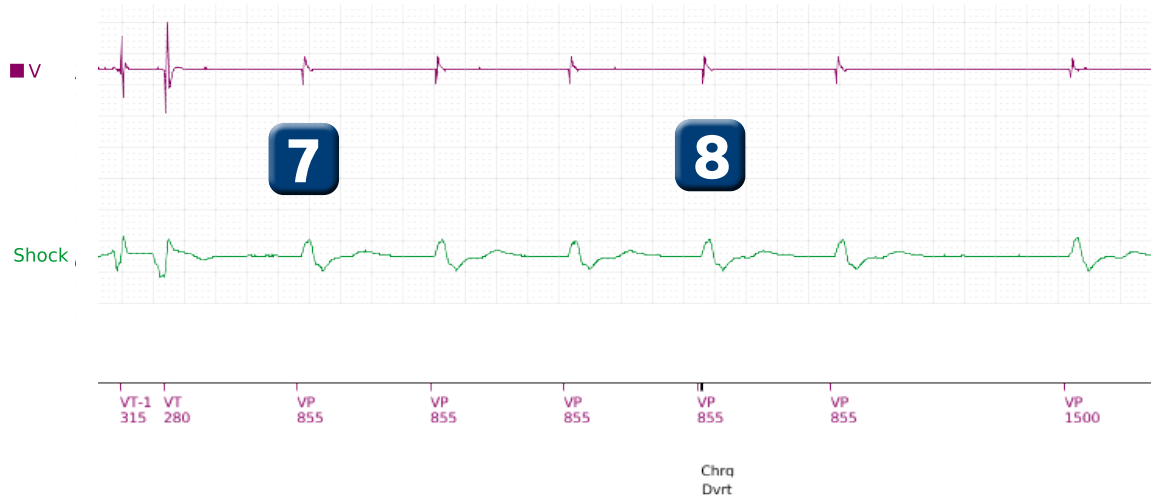
EGM layout

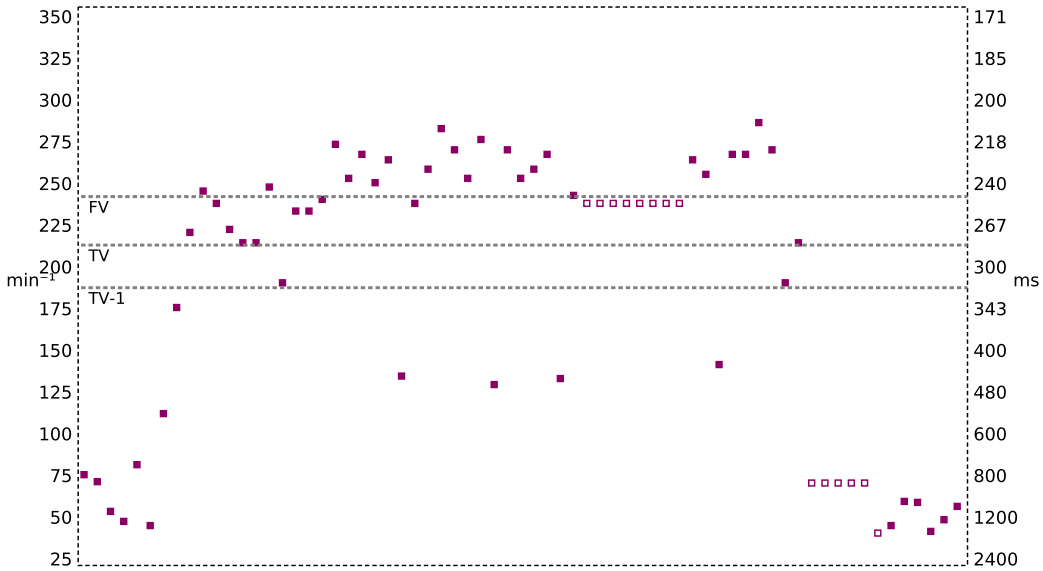
1. spontaneous polymorphic ventricular arrhythmia
2. V-Epsd marker (criterion 8/10 fulfilled) for VT-1 zone (1 VT-1 cycle, 5 VT cycles, 2 VF cycles)
3. 8/10 criterion for the VT zone; the initial detection time for the VT zone begins on this beat
4. 8/10 criterion for the VF zone; initial detection time for the VF zone begins on this beat
5. end of duration for the VF zone; burst in the VF zone (ATP Quick-Convert)
6. ineffective burst and start of capacitor charging
7. spontaneous termination
8. criterion 6/10 no longer fulfilled; charge diverted


V
Shock
VS
VS 800
VS 848
VS 1125
VS 1278
VS 745


V
Shock
1
2
3
4
VS 1348
VS 538
VS 343
VT 273
VF 245
VT 253
VT 270
VT 280
VT 280
VF 243
VT-1 315
VT 258
VT 258
VF 250
VF 220
VF 238
VF 225
VF 240
VF 228
VS 448
VT 253
VF 233
VF 213
VF 223
U0% U0% U14% U-- U31% V-Epsd U-- U-- U-- U-- U-- U-- U-- U0% U-- U-- U-- U--


V
Shock
5
6
VF 238
VF 218
VS 465
VF 223
VF 238
VF 233
VF 225
VS 453
VF 248
VP 253
VP 253
VP 253
VP 253
VP 253
VP 253
VP 253
VP 253
[VS] --
VF 228
VF 235
VS 425
VF 225
VF 225
VF 210
VF 223
U-- U-- U0% U-- U-- U-- U-- RID-V-Dur RID-V-Detect Chrg





Patient 2

- male with ischemic cardiomyopathy; implanted with Autogen dual-chamber defibrillator

Summary

- episode classified in the VF zone
- ATP in the VF zone
- diverted charge

EGM layout

1 sinus rhythm and ventricular pacing

2 ventricular extrasystole occurring in the ventricular noise window after atrial pacing (VS marker in square brackets); no pacing inhibition and ventricular pacing (VP) at the end of the programmed AV delay.

3 spontaneous polymorphic ventricular arrhythmia

4 V-Epsd marker (criterion 8/10 fulfilled); criterion fulfilled for VT-1 zone (1 cycle in VT-1 zone + 1 cycle in VT zone + 6 cycles in VF zone); initial detection time for VT-1 zone begins on this beat

5 8/10 criterion for VT zone; initial detection time for the VT zone begins on this beat

6 8/10 criterion for VF zone; initial detection time for the VF zone begins on this beat

7 end of duration for VF zone

8 burst in VF zone (ATP Quick-Convert)

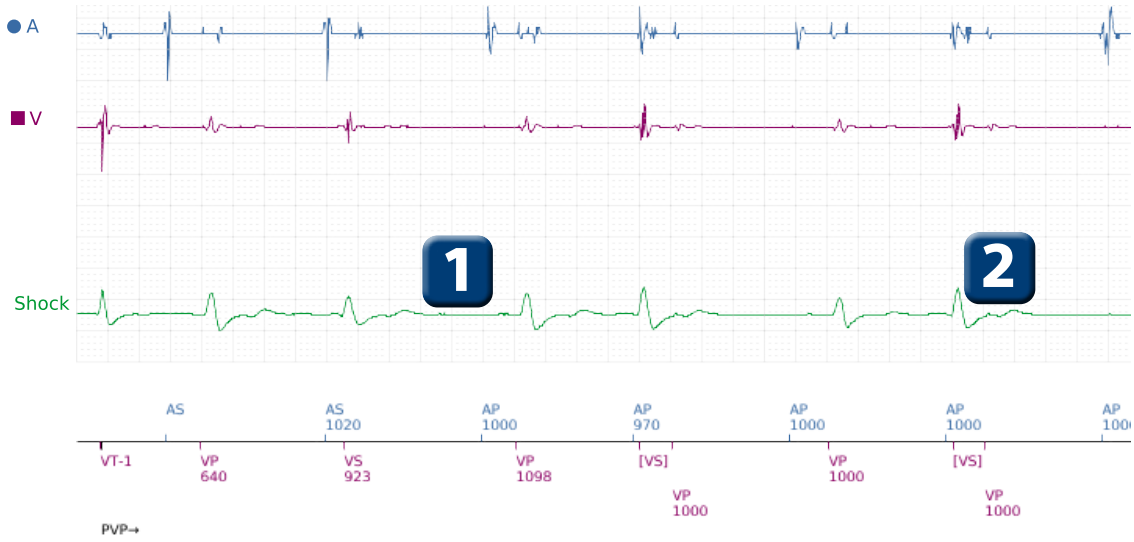
9 ineffective burst and start of capacitor charging

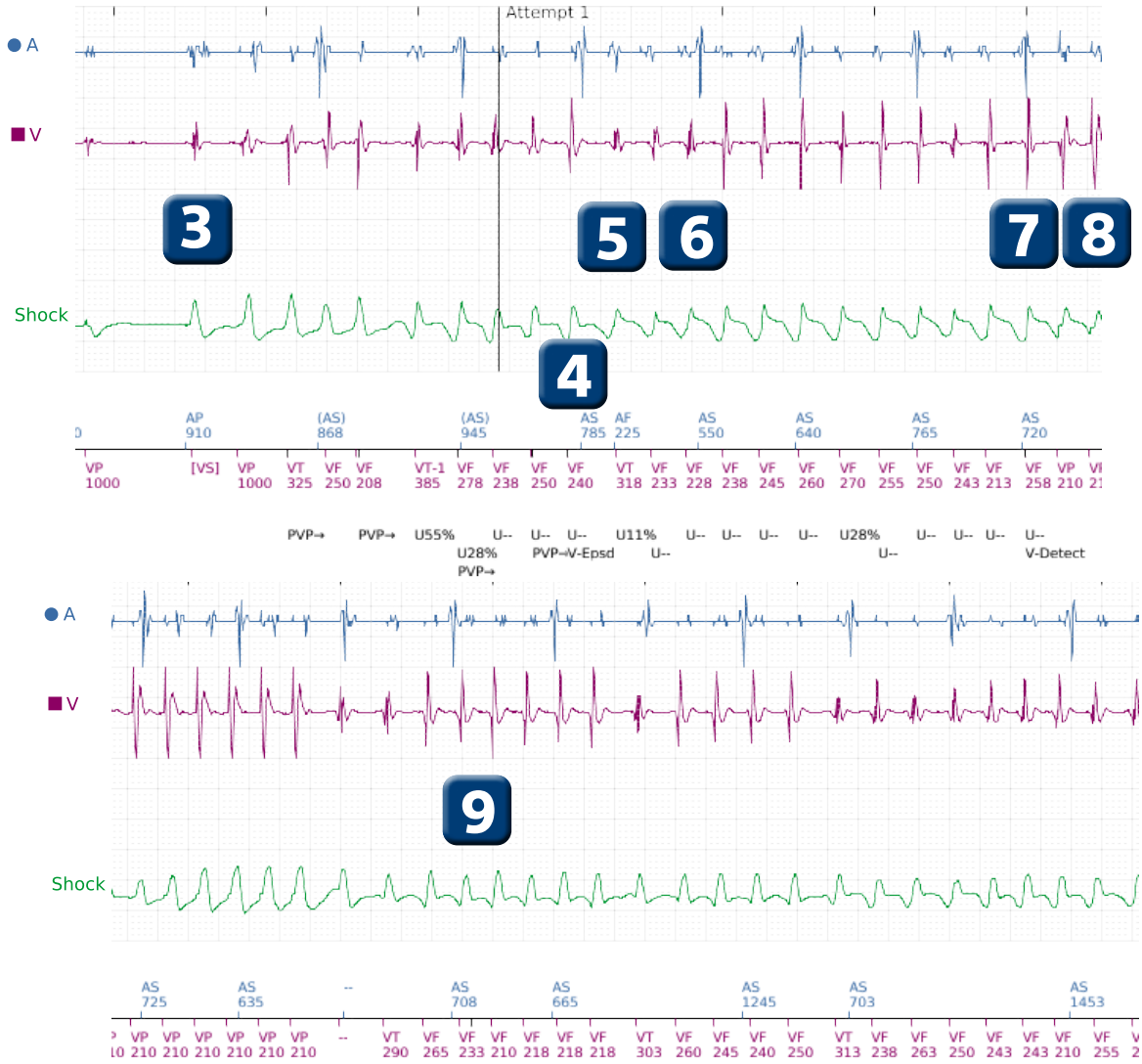
10 spontaneous termination

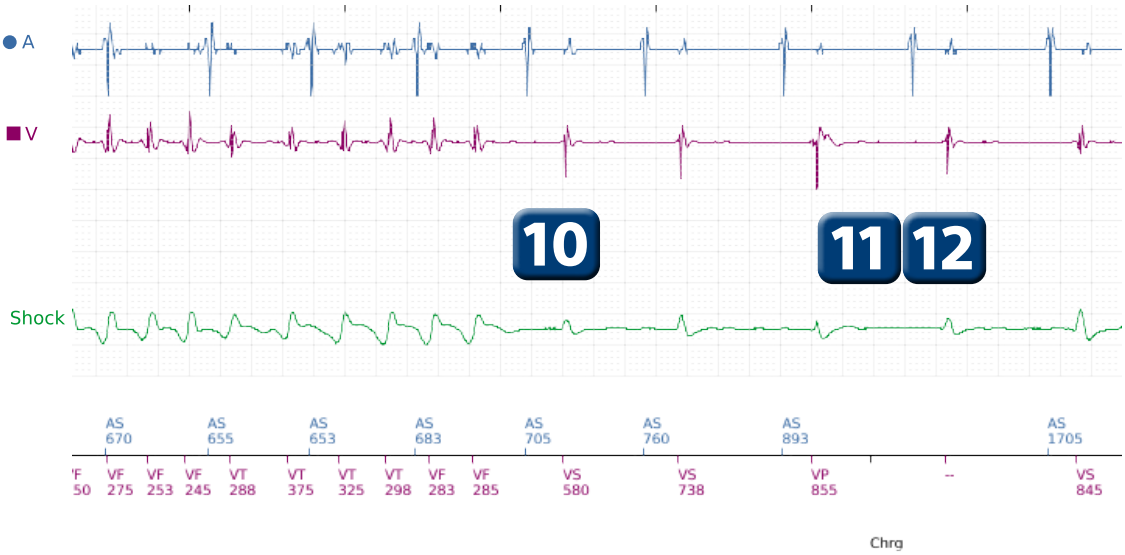
11 end of charge and start of 500 ms diversion window

12 the first ventricular cycle following the 135 ms end-of-charge blanking is not counted (--)

13 2 slow cycles out of 3; diverted charge


A
V
Shock
1
2
AS
AS 1020
AP 1000
AP 970
AP 1000
AP 1000
VT-1
VP 640
VS 923
VP 1098
[VS]
VP 1000
[VS]
VP 1000
VP 1000
PVP→

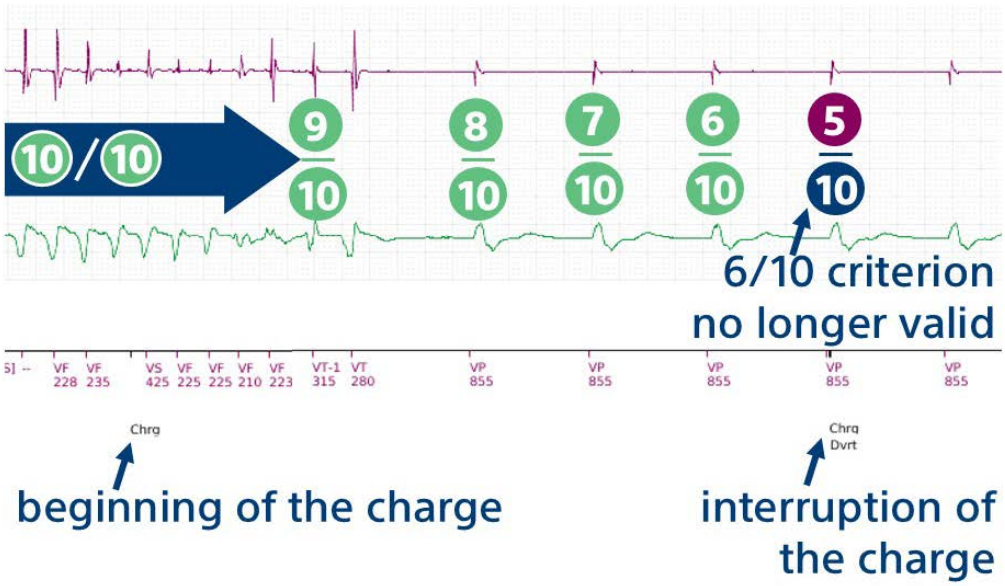

Attempt 1
A
V
Shock
3
4
5
6
7
8
9
AP 910
(AS) 868
(AS) 945
AS 785
AF 225
AS 550
AS 640
AS 765
AS 720
VP 1000
[VS]
VP 1000
VT 325
VF 250
VF 208
VT-1 385
VF 278
VF 238
VF 250
VF 240
VT 318
VF 233
VF 228
VF 238
VF 245
VF 260
VF 270
VF 255
VF 250
VF 243
VF 213
VF 258
VP 210
PVP→
PVP→
U55%
U28%
PVP→
U--
U--
PVP→V-Epsd
U--
U11%
U--
U--
U--
U--
U--
U28%
U--
U--
U--
U--
V-Detect
AS 725
AS 635
--
AS 708
AS 665
AS 1245
AS 703
AS 1453
VP 210
VP 210
VP 210
VP 210
VP 210
VP 210
--
VT 290
VF 265
VF 233
VF 210
VF 218
VF 218
VF 218
VT 303
VF 260
VF 245
VF 240
VF 250
VT 313
VF 238
VF 263
VF 250
VF 243
VF 243
VF 210
VF 255



Points to remember

- the main aim of programming is to reduce, as far as possible, the number of inappropriate or avoidable therapies; programming an initial duration of 5 seconds in the VF zone and a first shock of maximum output as first-line treatment (i.e. with a charge duration of more than 8 seconds) extends the delay between the onset of arrhythmia and shock delivery, allowing spontaneous termination; these 2 tracings show 2 episodes of ventricular arrhythmia with spontaneous termination and interruption of charging or charge diversion after the diversion window

- shock therapy can be programmed to be reconfirmed or not reconfirmed; the aim of reconfirmation is to prevent delivery of an unnecessary shock when the arrhythmia has spontaneously terminated; the device looks for spontaneous termination during and immediately after capacitor charging
- if the Shock not reconfirmed function is set to On, the shock is systematically delivered synchronized to the first sensed R wave following a 500 ms delay at the end of capacitor charging (whether the arrhythmia is sustained or not); therefore, if capacitor charging begins, the shock is automatically delivered
- if the Shock not reconfirmed function is set to Off, charging can be interrupted if the device diagnoses spontaneous termination; if 5 slow beats (sensed or paced) are counted within a detection window of 10 beats (6/10 fast criterion not fulfilled), the device interrupts charging (first trace); if the charge has been completed, post-charge reconfirmation is performed at the end of the charge; after the post-charge refractory period and the first uncounted sensed event, if 2 of the 3 post-charge intervals have a rate below the lowest rate threshold, the shock is not delivered.



This figure shows the charge interruption following spontaneous reduction and the detection of 5 consecutive slow cycles.

6 Diversion window at end of a charge

Patient

- male with ischemic cardiomyopathy; implanted with a Resonate triple-chamber defibrillator; paroxysmal AF

Summary

- episode classified in the VF zone
- 41 Joule shock with a charge time of 11 seconds
- 64 Ohm shock impedance

EGM layout

1 AF and bi-ventricular pacing

2 spontaneous, very rapid, polymorphic ventricular arrhythmia detected in the VF zone

3 V-Epsd marker (criterion 8/10 fulfilled) for the VF zone; initial detection time for the VF zone begins

4 end of duration (V-Detect)

5 start of capacitor charging

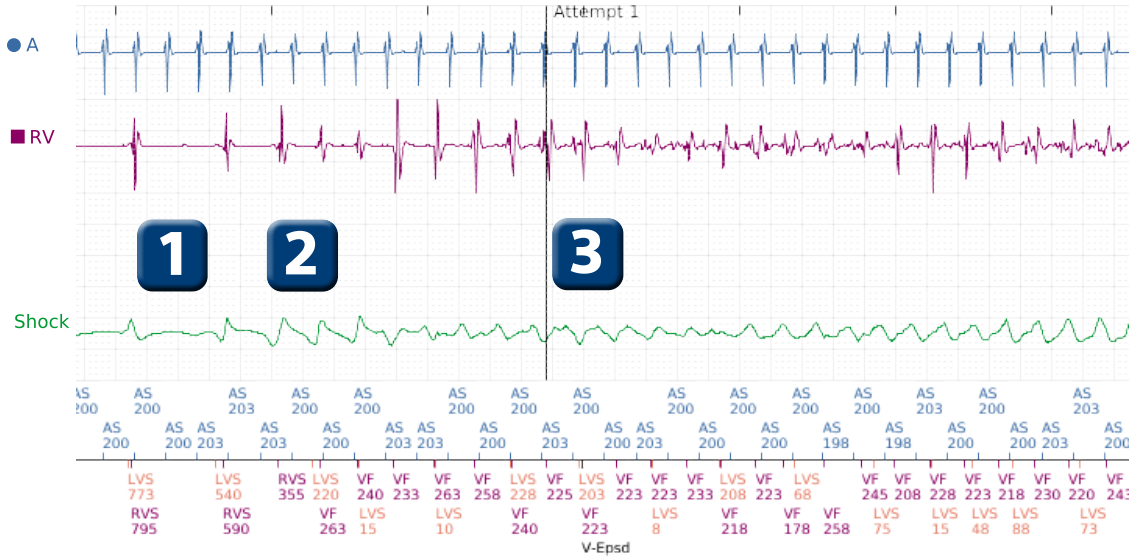
6 end of charge; this charge lasted approximately 11 seconds, with the magnitude of the shock delivered corresponding to the maximum output of the device

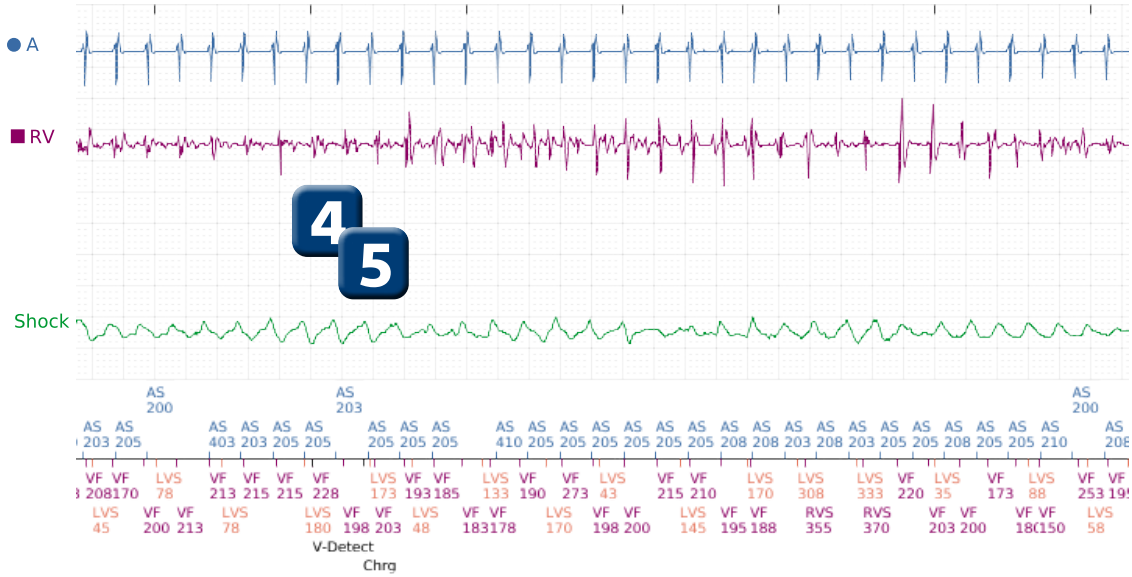
7 a refractory period of 135 ms begins at the end of the charge; the first cycle following this refractory period is not counted (--)

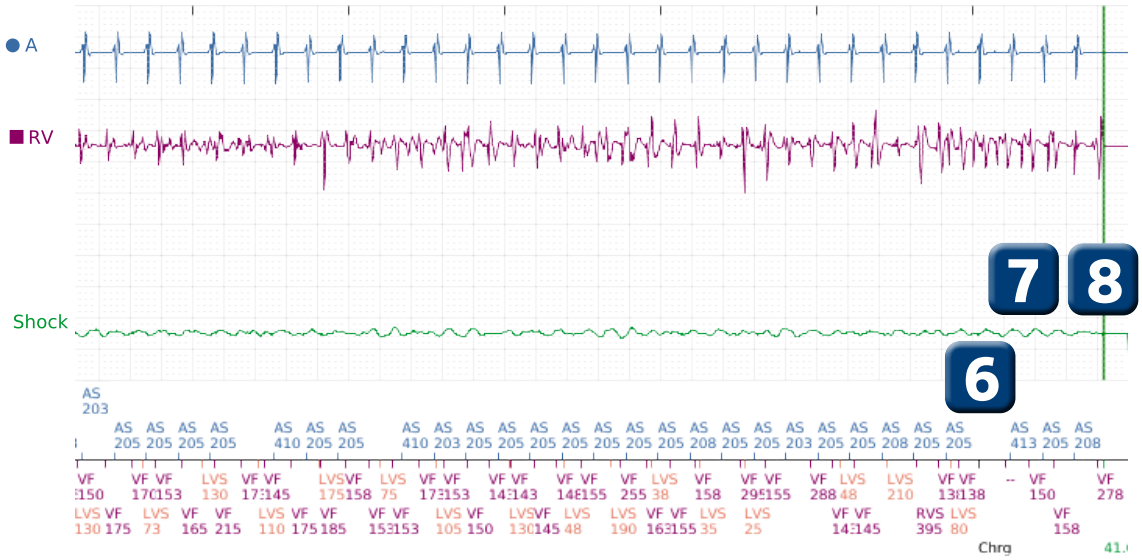
8 the following 2 cycles are fast (VF) but the charge diversion window has not elapsed (500 ms after the end of the charge); the shock cannot be delivered during this window and the device waits for the next cycle (the third) to deliver a synchronized shock.

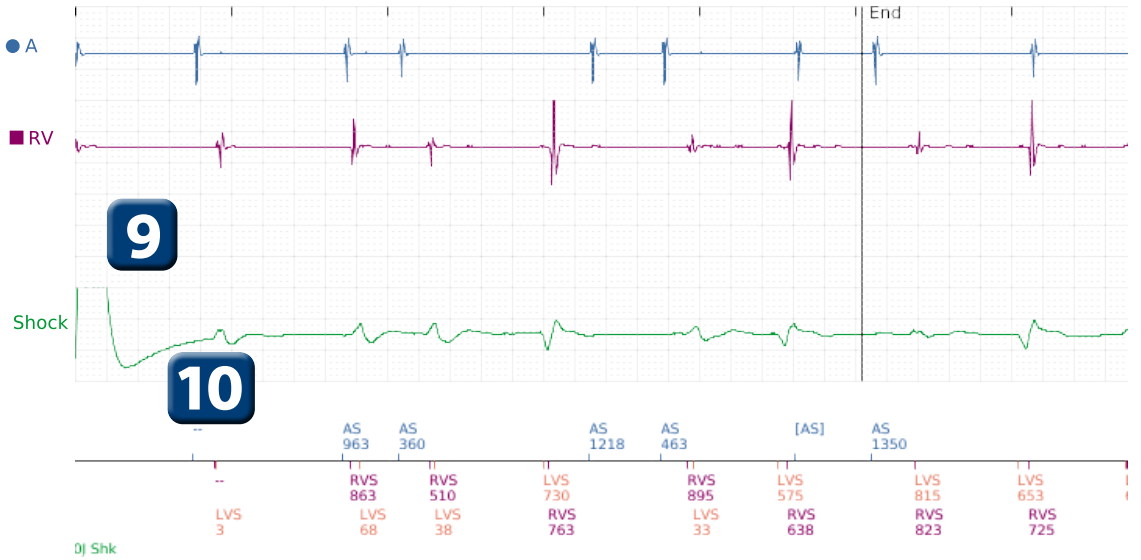
9 shock terminates ventricular and atrial arrhythmias

10 the first atrial cycle and the first ventricular cycle following the post-shock refractory period (500 ms) are not counted (--)






A
RV
Shock
7
8
6
Chrg


A
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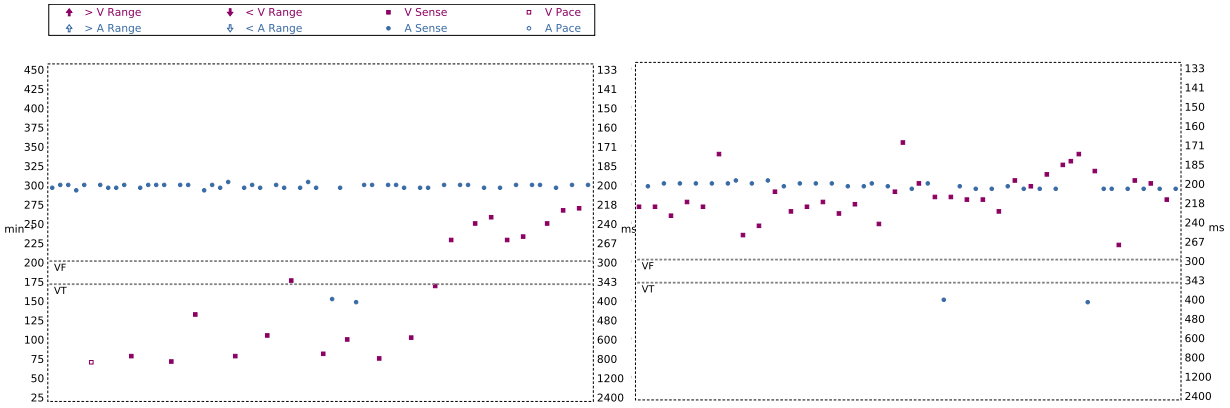
0J Shk


> V Range
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V Sense
V Pace
> A Range
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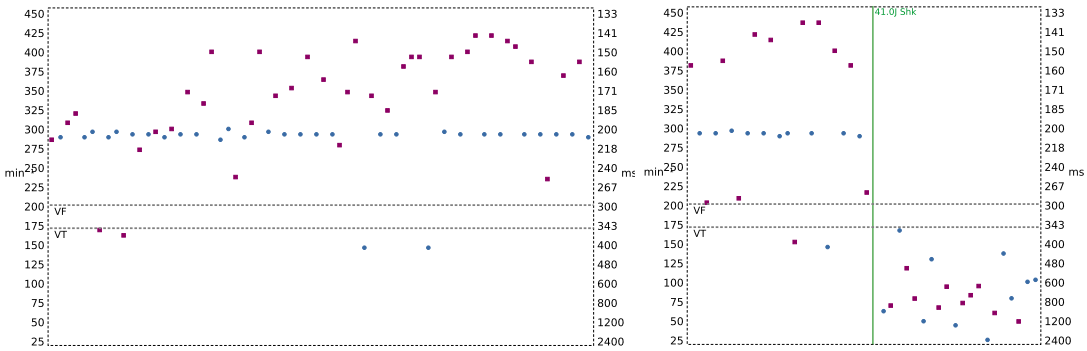
A Sense
A Pace
min
ms
VF
VT

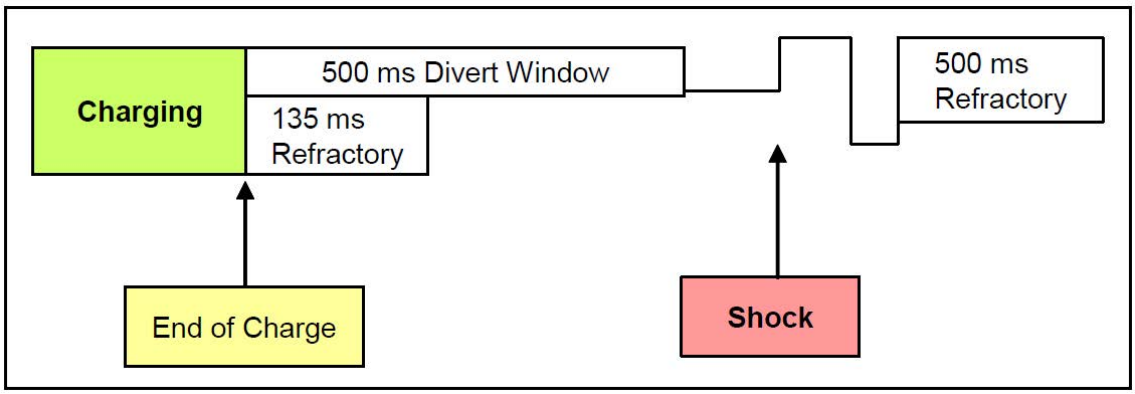


Points to remember

- at the end of capacitor charging, the diversion window begins, which lasts 500 ms; this 500 ms delay provides a minimum reaction time to activate the divert command on the programmer (opportunity for the doctor to cancel the shock from the programmer)
- the first 135 milliseconds of this diversion window corresponds to a refractory period when no atrial or ventricular sensing is possible; the ventricular cycle following this refractory period is not counted (--); operation then differs according to programming (Shock not reconfirmed On or Off)
- if the Shock not reconfirmed function is set to On, the shock is systematically delivered synchronized to the first sensed R-wave following the 500 ms delay at the end of capacitor charging (whether the arrhythmia is sustained or not); if no R-wave is sensed within 2 seconds of the end of charging, the ventricular shock is administered asynchronously at the end of the 2-second delay
- if the Shock not reconfirmed function is set to Off, following the uncounted cycle, the device measures the next 3 intervals and compares them with the minimum rate threshold ; if 2 of the 3 intervals have a rate higher than the lowest rate threshold (lowest programmed tachycardia zone: VF zone if only 1 zone programmed, VT zone if 2 zones

and VT-1 zone if 3 zones), the shock is delivered synchronized to the second rapid event; if 2 of the 3 intervals have a rate below the lowest rate threshold, the shock is not delivered; if there is no sensed beat, pacing begins at the programmed lower rate after a period of 2 seconds and the charge is diverted.

- in this example, it can be seen that the shock is synchronized to the third fast cycle; in fact, even if the 2 cycles that follow are fast (VF), the charge diversion window has not elapsed when the second fast cycle occurs (less than 500 ms after the end of charging); the shock cannot be delivered during this diversion window; the device therefore waits for the next cycle (the third) to deliver a synchronized shock.
- following a shock, there is a non-programmable refractory period of 500 ms



This figure shows the divert window at the end of the charge (500 ms with an initial refractory period of 135 ms) and the 500 ms refractory period following the shock.

7 Undersensing and charge diversion

Patient

- 40-year-old man implanted with an Incepta single-chamber defibrillator for spontaneous type 1 Brugada syndrome with a syncopal episode
- ventricular lead positioned at the septum with average sensing of 3.5 mV in sinus rhythm
- induction of VF at the end of the implantation procedure with ventricular sensitivity at 1 mV

Summary

- episode of induced VF
- charge diverted due to reconfirmation failure (abandoned attempt)
- the arrhythmia is redetected and a 21 Joule shock is delivered following a very short charge time (the device had previously charged its capacitors, but therapy was abandoned)

EGM layout

1. very short charge time to deliver the shock on the T-wave (start and end of charge markers very close together)
2. series of 8 paced impulses at a very fast rate (200 beats/minute)
3. low-amplitude shock delivered on the T wave; there is a refractory period of 500 ms after shock delivery when no sensing is possible in both chambers
4. after the refractory period, the first ventricular event is not counted (--)
5. onset of a polymorphic arrhythmia with very low voltages

6 detection of an episode (V-Epsd) after 8 consecutive cycles in the VF zone (8/10 detection window criterion fulfilled),

7 first ventricular event is undersensed

8 after duration (1 second), detection of a sustained episode (V-Detect); start of capacitor charging

9 end of charge

10 the shock is diverted by the device (Dvrt) in the absence of reconfirmation after the end of the charge; the criterion of 2 out of 3 rapid cycles is not met; ventricular under- sensing is responsible for a false diagnosis of spontaneous arrhythmia termination

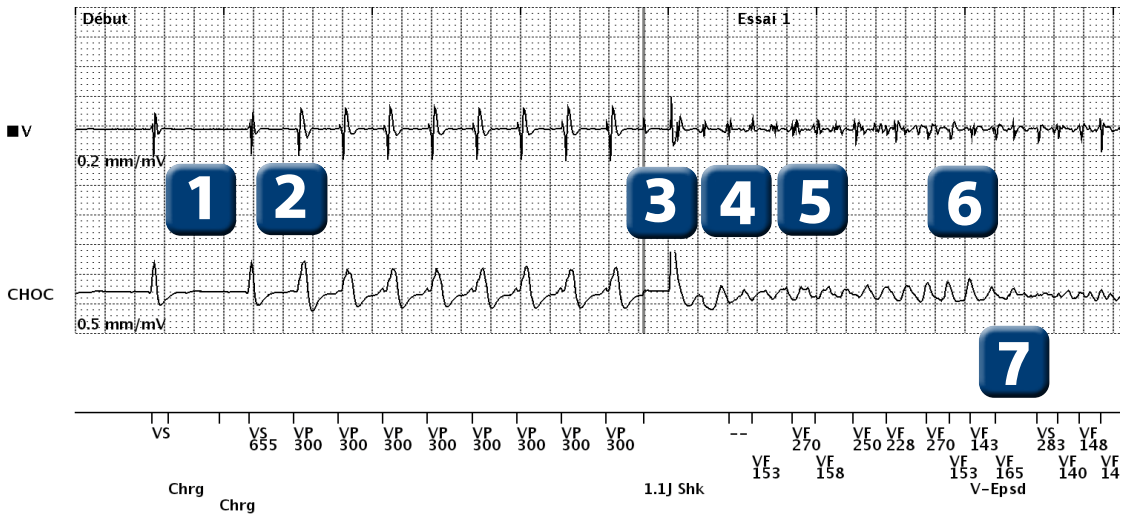
11 new detection window of 8 rapid cycles out of 10; start of post-detection duration

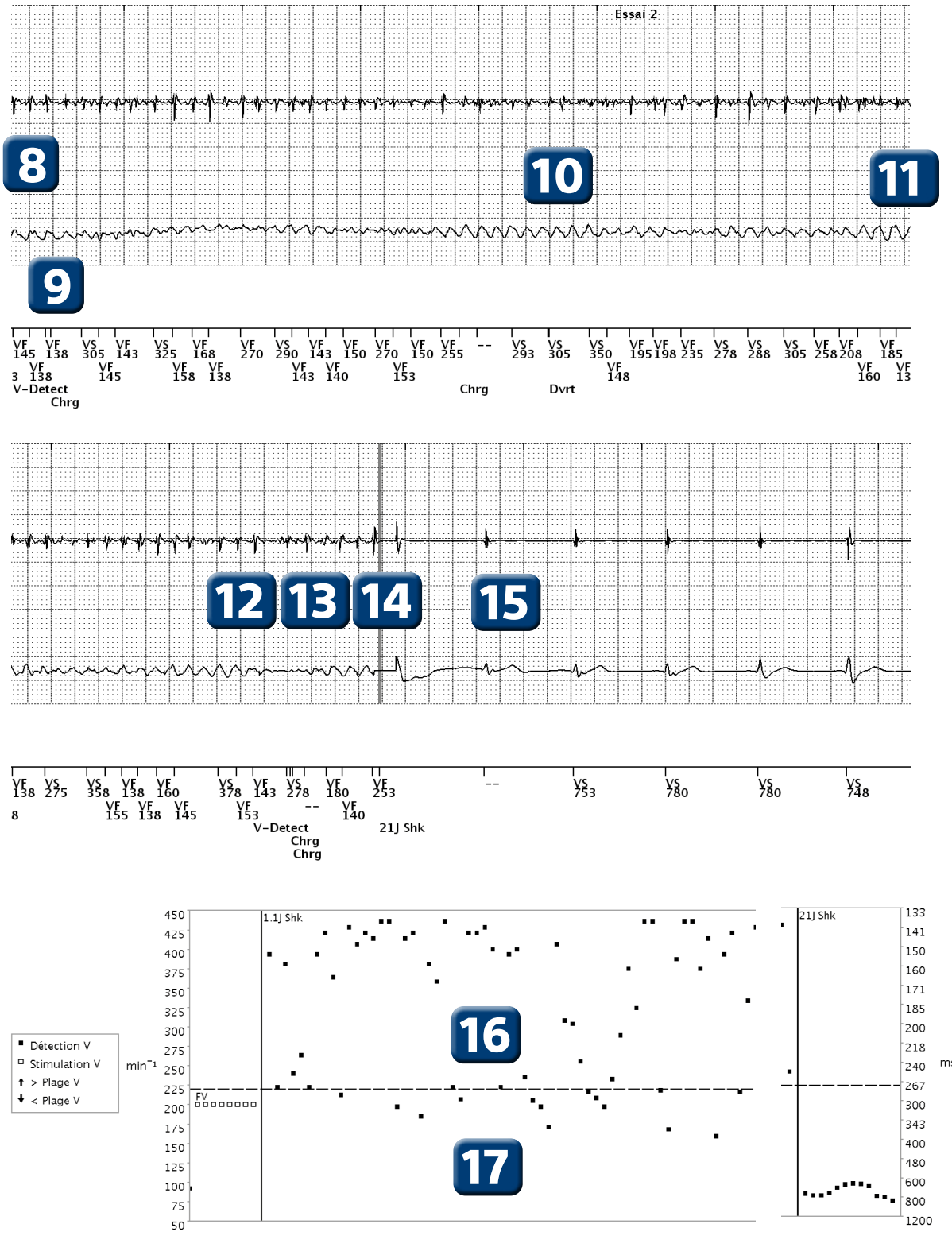
12 new detection of episode in VF zone (8/10 in VF zone and post-detection duration satisfied)

13 new, very short duration charge, the previous charge having had no time to dissipate

14 this shock is not reconfirmed; it is delivered following the 500 ms period at the end of charging; when a charge is diverted, the following charge for the same episode is systematically delivered due to fear of ventricular undersensing causing an incorrect diagnosis of spontaneous termination.

15 effective shock and arrhythmia termination





The appearance of this plot is characteristic of intermittent VF under- sensing, with a succession of fast cycles in the VF zone (16) and slower cycles oscillating around the sinus zone (17), evidenced by the gaps in the interval plot.

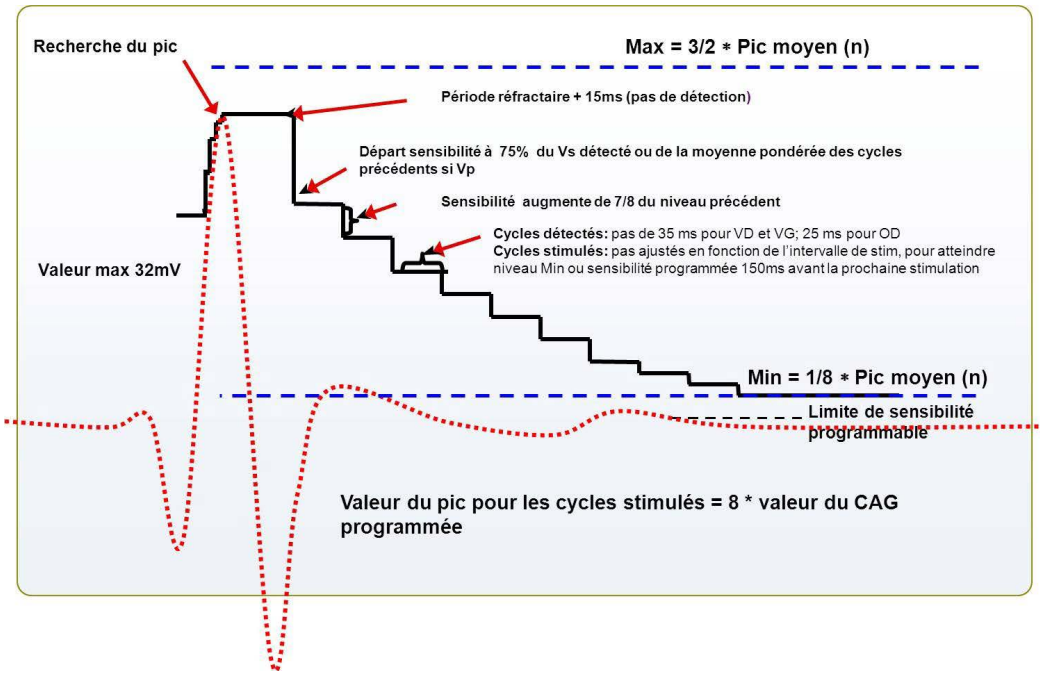
Points to remember

- proper defibrillator operation requires perfect sensing of the fast, low-amplitude signals of ventricular fibrillation, while simultaneously not sensing other intracardiac (non – QRS complexes) or extracardiac signals; this means programming a high sensitivity and short refractory periods; the sensitivity threshold is not programmed to a fixed value, but adapts automatically in relation to the amplitude of the preceding R wave; sensitivity then increases during the cycle, in order to search for any low-amplitude signals
- Boston Scientific devices operate with a digital automatic gain control (AGC) that dynamically adjusts the sensitivity level in the atrium and ventricle; on a triple-chamber defibrillator, each channel operates with its own automatic gain control (atrial AGC, right ventricular AGC and left ventricular AGC)
- before being measured, a signal is filtered according to its frequency; a bandwidth between 20 and 85 Hz is used in new-generation Boston Scientific defibrillators (the frequency of a T wave is typically between 0 and 10 Hz); a 12-bit converter converts the electrical signal into a digital value
- to optimize sensing of VF signals (fast and irregular), the device adjusts ventricular sensitivity using an automatic gain control with 2 components: slow and fast
- the AGC uses a so-called «slow» component to set a search interval for the amplitude of the next QRS; by calculating an «average» of the peaks of the preceding signals, the «slow» component defines a zone in which the next peak is likely to be found and sets this zone between a minimum and maximum value
- after a ventricular event, the «fast» component of the AGC maintains a high sensitivity value after sensing, then decrements the sensitivity value progressively to make the device more and more sensitive; at the end of the refractory period + 15ms, the value drops to 75% of the detected peak, or 75% of the mean peak if the last ventricular event is paced; for a sensed QRS, the AGC then decreases the value to 7/8 of the previous value every 35ms; this decrease continues until the highest value between the Min or the programmed sensitivity value is reached; if the last ventricular event is paced, the

AGC then decreases the value to 7/8 of the previous value at each step, but the length of the step is determined by the lower rate limit: the Min value (or the programmed sensitivity value) will be reached 150ms before the next paced event.

- correct arrhythmia sensing is an essential prerequisite for shock treatment of VF; during the induction test, the maximum ventricular sensing sensitivity is usually decreased (programming of a ventricular sensitivity of 1 to 1.5 mV) so as to place the system under poor sensing conditions and increase the sensitivity of the test; good VF detection with this high value suggests a good sensing safety margin with the nominal value of 0.6 mV which will then be applied
- the presentation is simple in 2 situations: 1) sensing quality is perfect throughout initial detection, duration and capacitor charging, and the safety margin in terms of sensitivity programming is deemed satisfactory; 2) sensing quality is poor, with sensing faults so frequent that the initial detection criteria are never met or the charge is systematically diverted and no therapy can be delivered; in this case, a change in lead positioning is required to obtain appropriate sensing.
- sometimes, as in this patient's case, the situation is more difficult to manage; in fact, during induction, the operator noted some ventricular sensing defects; it is important to analyze the induction tracings meticulously so as not to miss these sensing gaps, which are sometimes difficult to diagnose because they only moderately delay the onset of the shock; in this example, the first charge is diverted and the delivery of the shock is delayed by a few seconds; the graph makes it easier to identify undersensing; undersensing is favored by signal amplitude variability, which fools the automatic sensitivity control; the VF signals in this patient are highly fragmented and of low amplitude on the sensing channel, which also favors under- sensing; ventricular sensing in sinus rhythm, measured at 3.5 mV, was of average quality; despite the effectiveness of the c shock, the operator decided to move the lead from the apex of the right ventricle to the upper part of the septum, a site which enabled a very slightly higher sensing (4.4 mV in sinus rhythm).

- in addition to the number of under-sensed cycles, the impact of undersensing is dependent on the detection phase; initially, 3 consecutive fast cycles are required; the detection of an episode then requires 80% fast cycles (criterion 8/10); once this criterion has been met (eliminating some oversensed episodes and extrasystoles), the device becomes a little less demanding during the initial duration and charging of the capacitors (60% rapid cycles required); at the end of charging, there is a certain «fragility» because if under-sensing occurs at this point and criterion 2/3 is not met, charging is diverted, as in this example (correct initial detection, but under-detection occurring at the end of charging).
- to avoid not treating VF with under sensing, only one capacitor charge can be diverted per episode and the duration of redetection is necessarily short in the VF zone (1 second non-programmable); at the end of the duration of redetection (after a diverted charge), if a second charge begins, the shock will always be delivered (the charge cannot be diverted)



This figure shows how automatic gain control works.

8 End-of-episode criteria following an electric shock

Patient

- 75-year-old man with ischemic cardiomyopathy; implanted with a Resonate triple-chamber defibrillator

Summary

- episode classified in VF zone
- 3 shocks of maximum output

EGM layout

1 atrial and bi-ventricular pacing

2 onset of rapid, polymorphic ventricular arrhythmia (VF)

3 start of VF zone duration (5 seconds)

4 end of duration and start of capacitor charging

5 end of charge and 41 Joule electric shock delivered on the second fast cycle (synchronized to the R wave)

6 VF restarts immediately

7 redetection criterion 8/10 verified (1 VT cycle, 7 VF cycles) for VT zone (start of duration for VT zone)

8 redetection criterion 8/10 verified for VF zone (start of post-shock duration for non-programmable VF zone of 1 second)

9 end of duration set at 1 second for VT zone (V-Dur); post-shock duration of VF zone is still active

10 end of post-shock time for VF zone (V-Detect) and capacitor charging

11 the shock is delivered at the end of the charge after the 500 ms post-shock window; when the shock is delivered, a 30-second period begins during which the device seeks to validate the 8/10 criterion.

12 effective shock

13 arrhythmia restarts before the end-of-episode criterion (less than 30 seconds after shock); on this cycle, criterion 8/10 verified; as the episode is not over, the device considers this to be the second shock and the post-shock duration of 1 second applies

14 end of post-shock period and capacitor charging

15 second shock

16 arrhythmia termination

17 interruption of the trace

18 restart of ventricular arrhythmia

19 V-Epsd End marker (end of episode) since it has been 30 seconds since the shock was delivered and criterion 8/10 has not been satisfied; VT and VF counters reset to 0

20 8/10 criterion verified for VT zone (1 VT cycle + 7 VF cycles from end-of-episode marker); start of initial VT zone duration

21 criterion 8/10 verified for VF zone; start of initial duration of VF zone

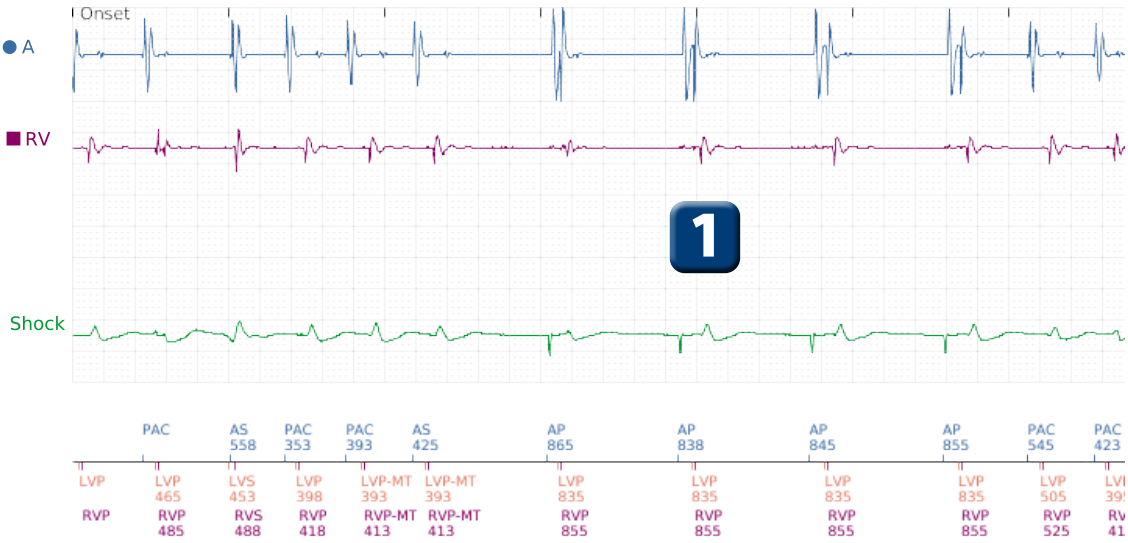
22 end of duration for VF zone; ATP Quick Convert (the device considers this to be the first therapy of a new episode)

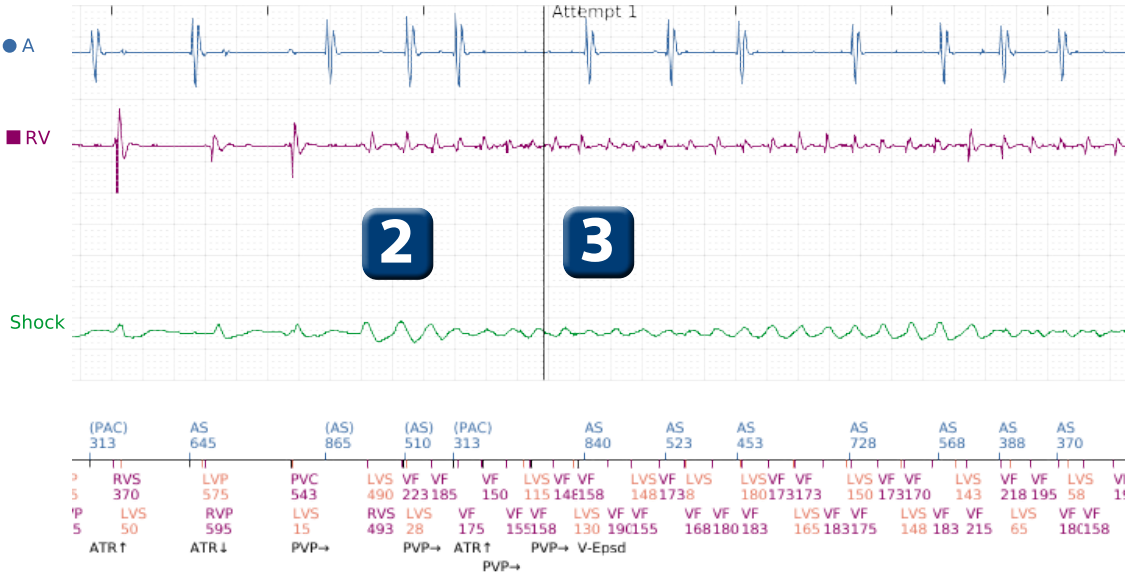
23 inefficient ATP, capacitor charging and electric shock

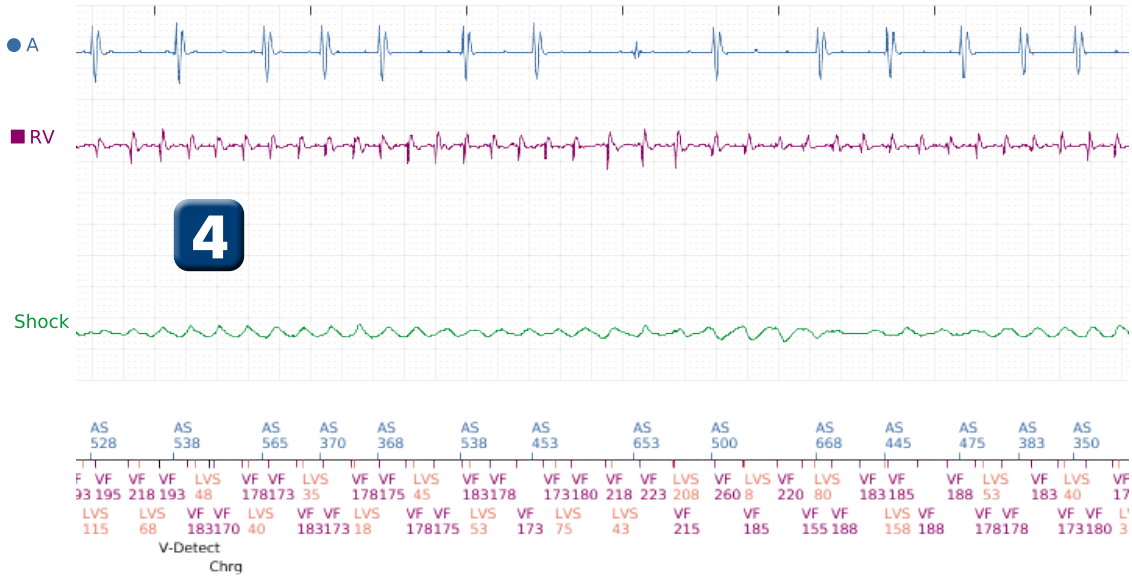
24 immediate recurrence of arrhythmia

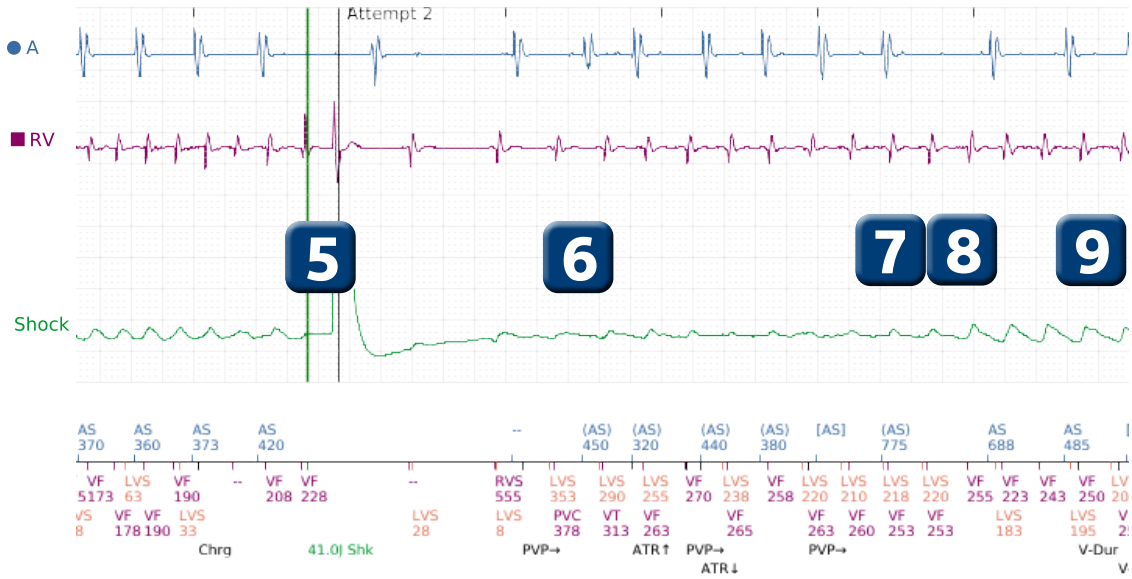
25 end of 1 second post-shock duration in VF zone

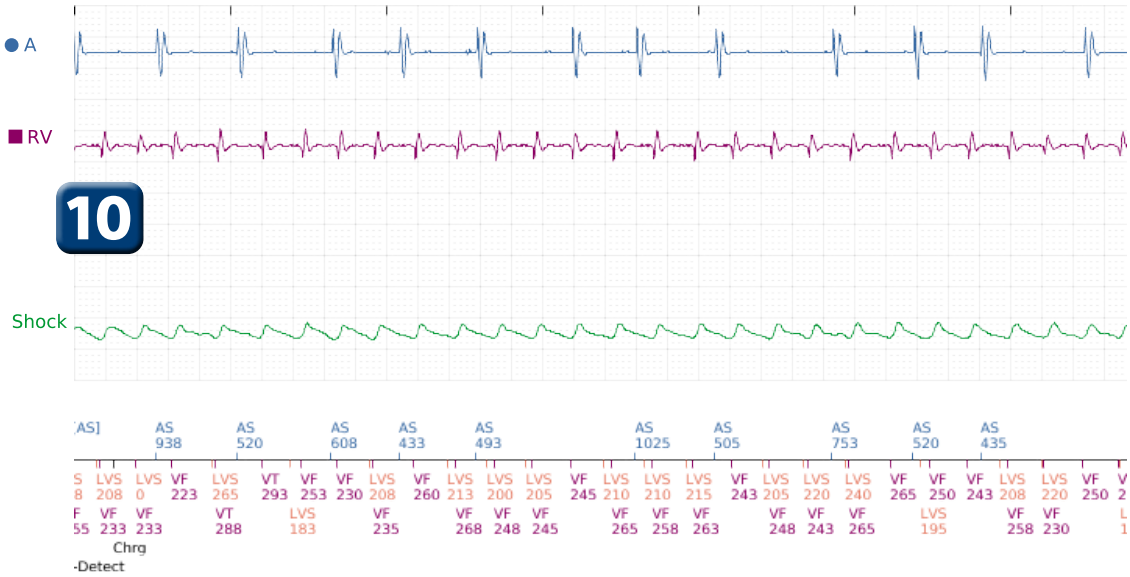
26 shock with VF termination

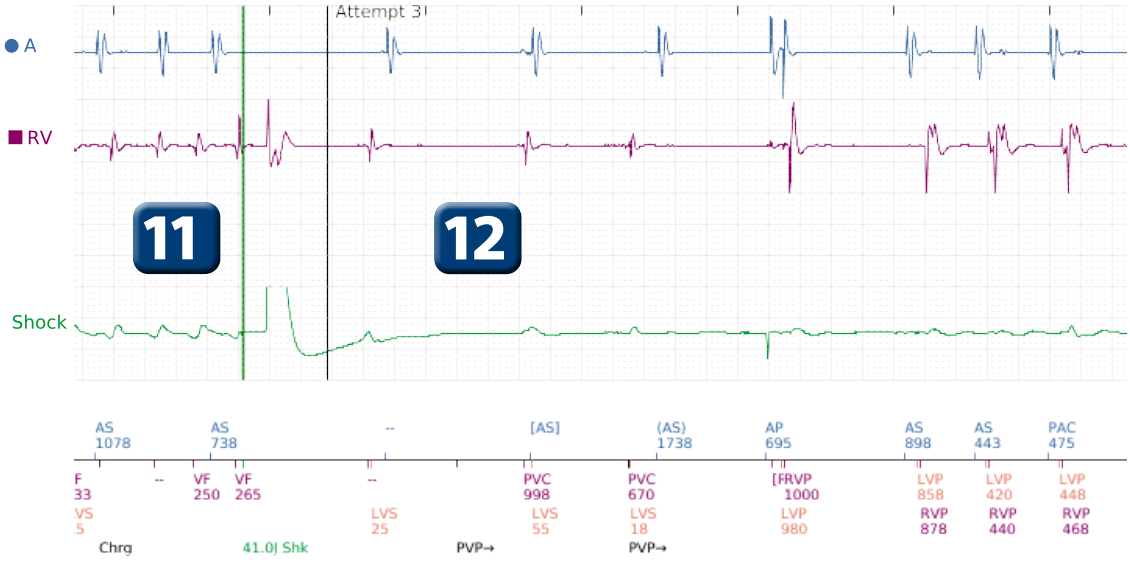


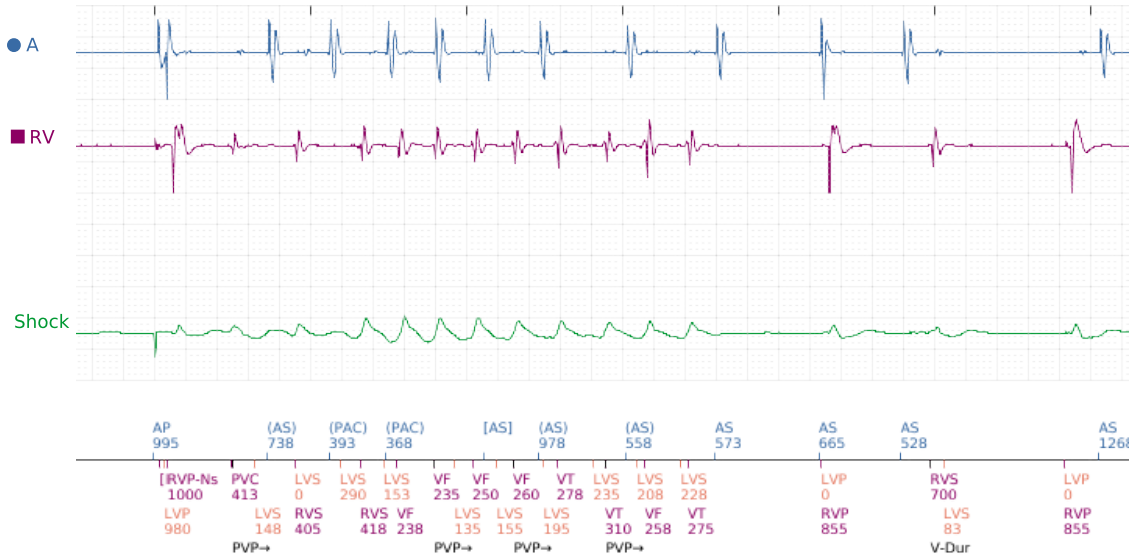


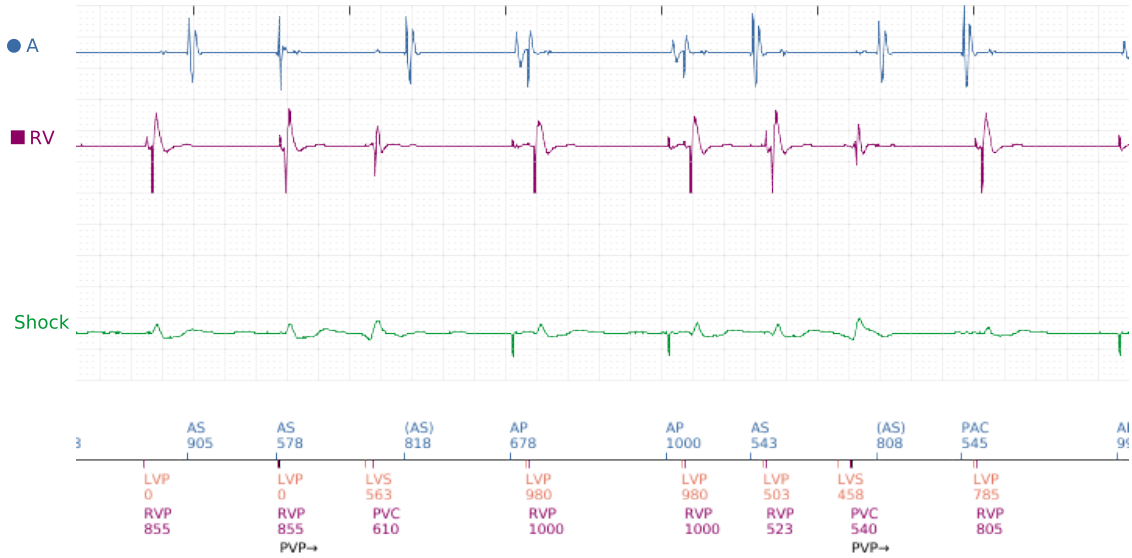












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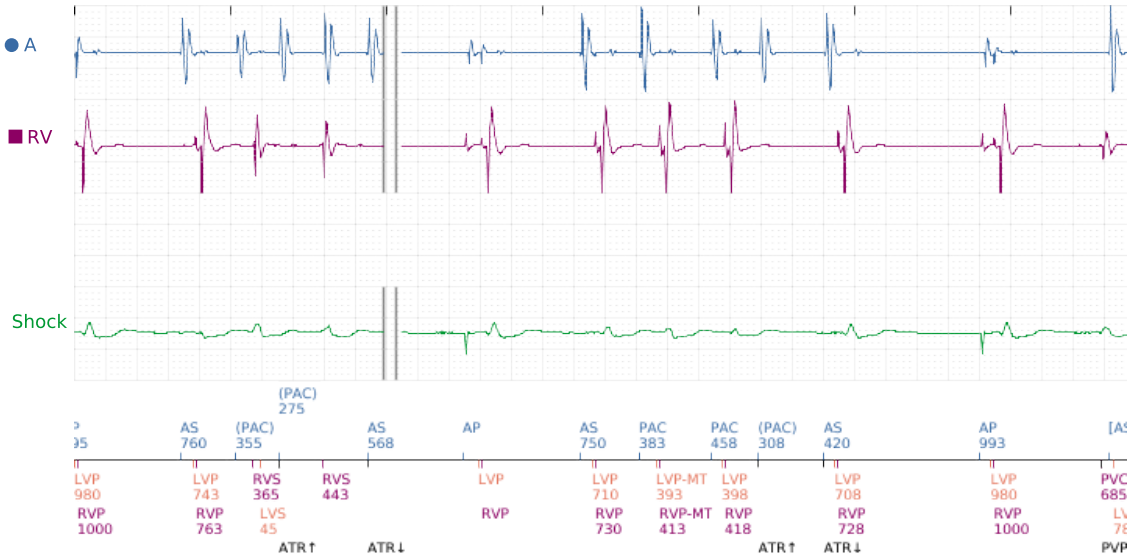

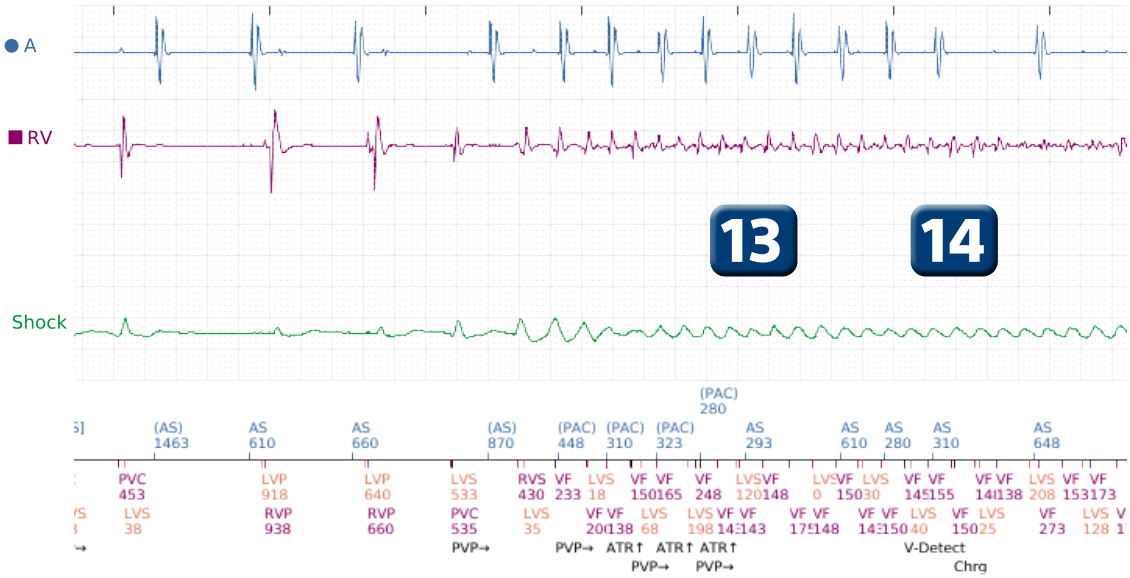

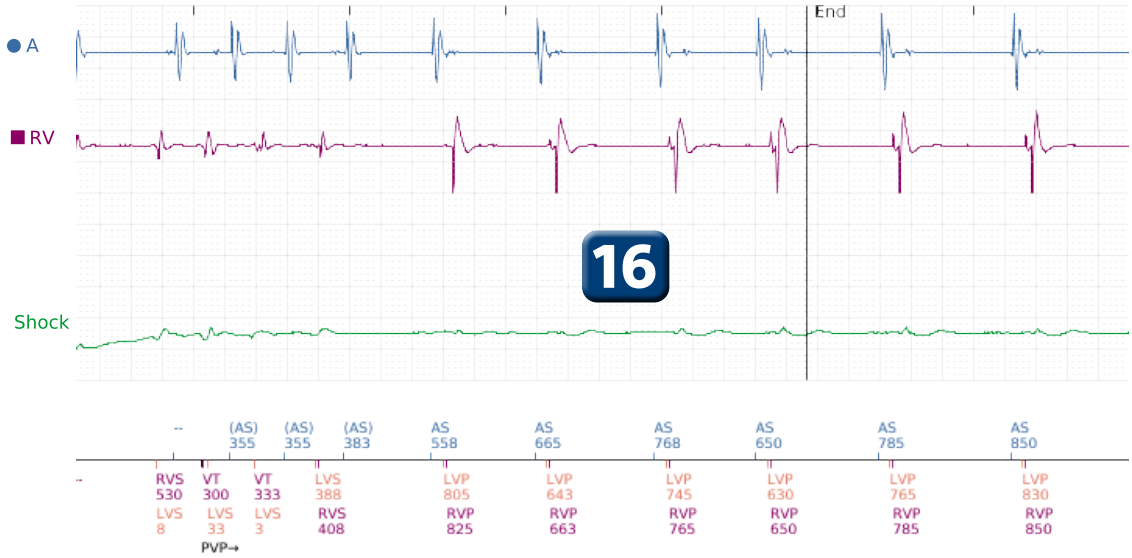

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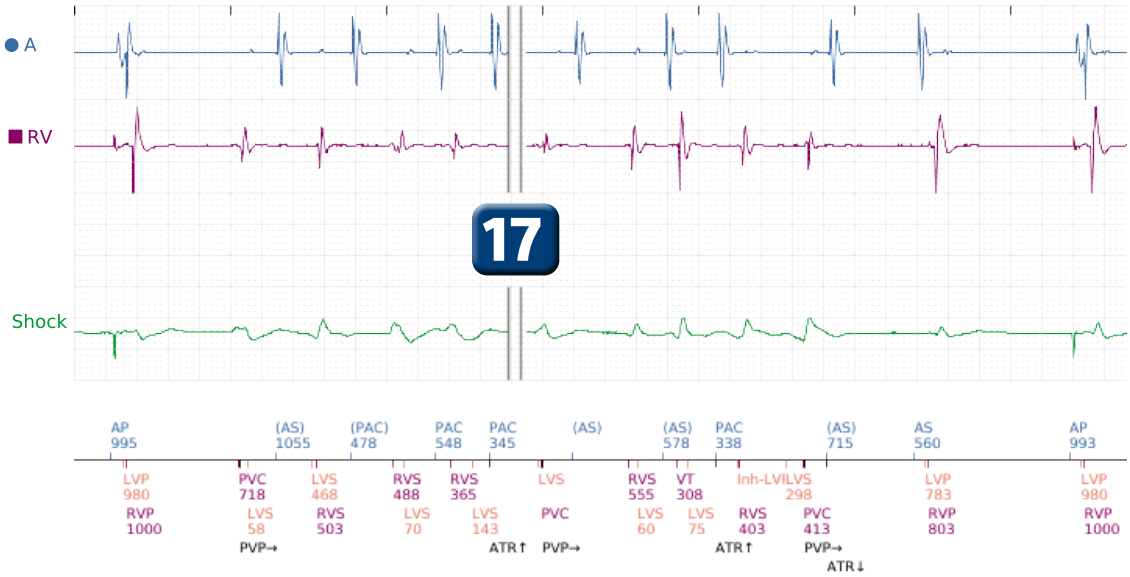

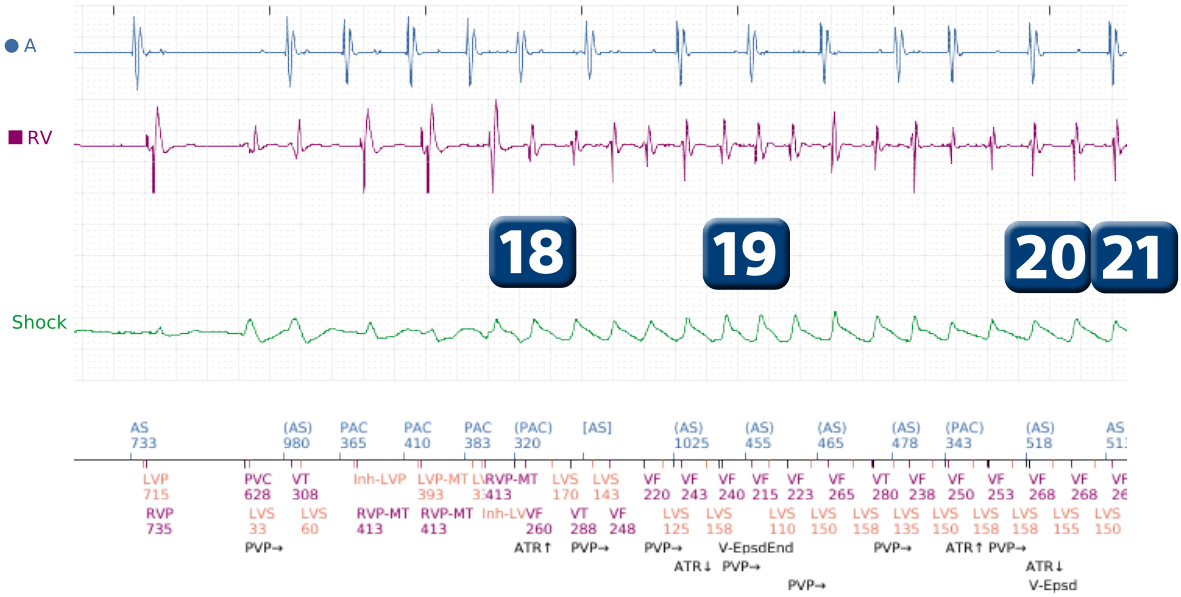

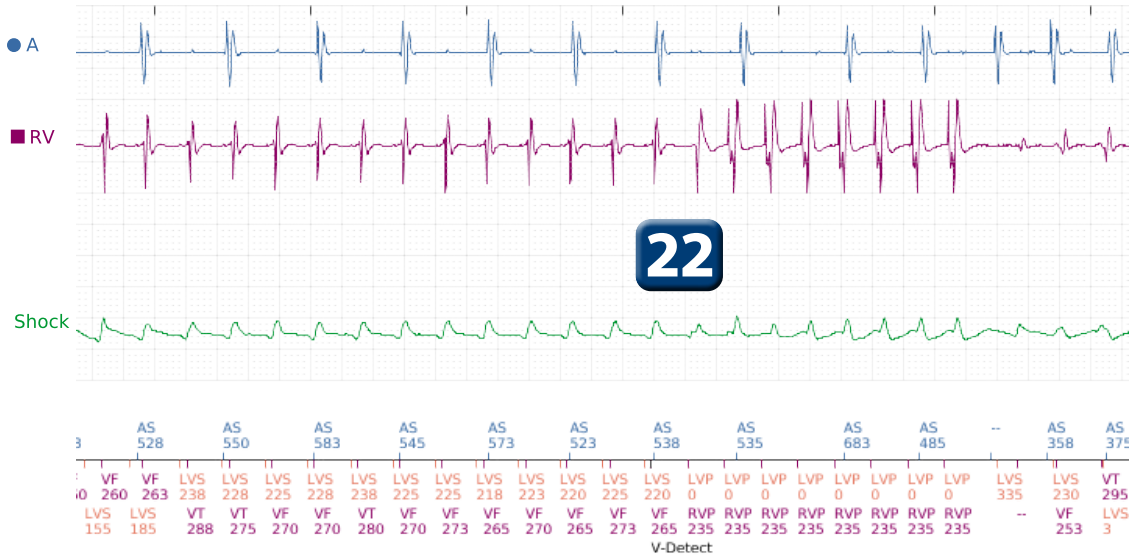

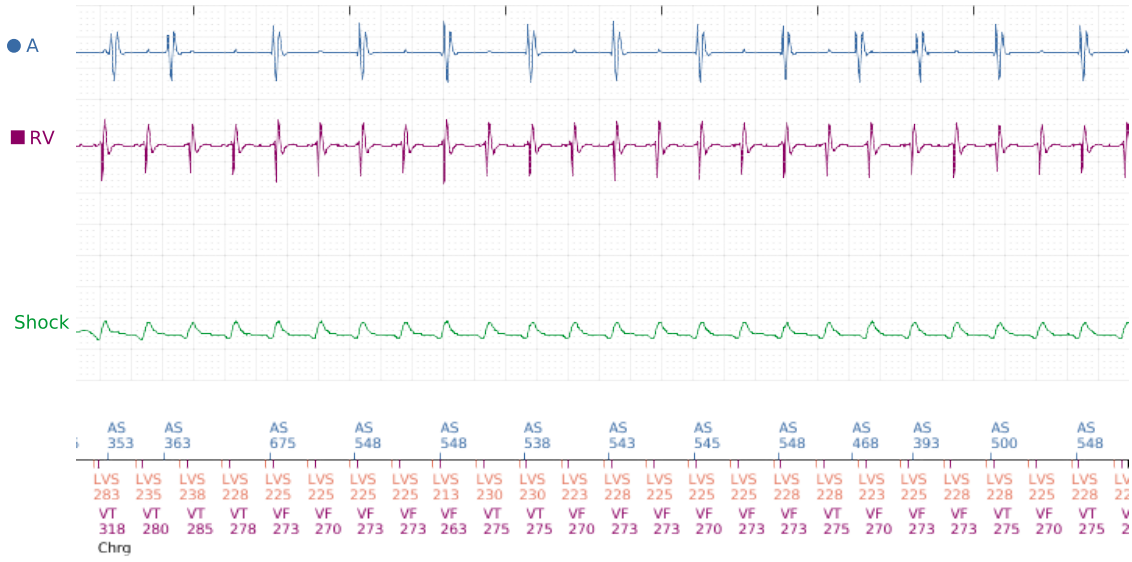

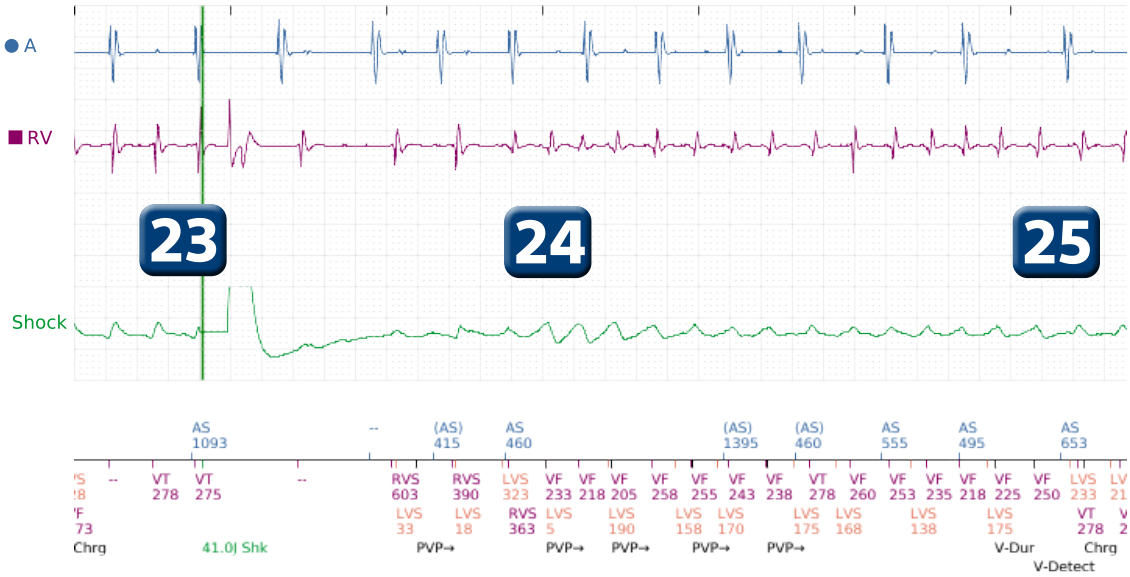
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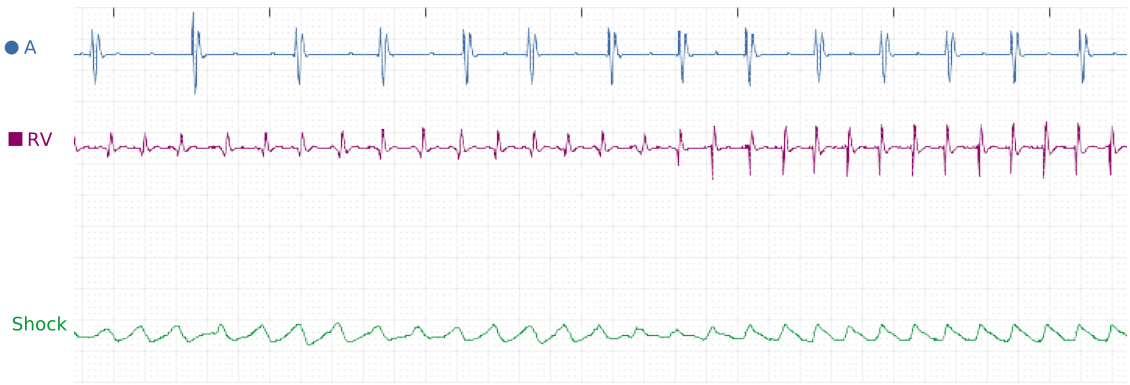
A
RV
Shock


A
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Shock
26

Points to remember

- this patient presented with multiple episodes of VF (in addition to those on this tracing), which makes it possible to detail the operation of the device once the shock has been delivered
- when a shock has been delivered, a non-programmable 30-second timer starts; if during these 30 seconds, criterion 8/10 is verified, the device considers that it is the same episode, the post-shock duration applies (1 second in VF zone) and the next therapy is delivered (shock number 2 if it was previously shock number 1); if during these 30 seconds, criterion 8/10 is not verified, the device considers the episode to be over; if the arrhythmia then recurs, the device considers it to be a new episode, the initial duration is applied (today's standard programming of a 5-second duration in the VF zone) and the first therapy in the VF zone is delivered.
- this operation can be problematic when the patient experiences effective shocks but relatively early recurrences of VF (less than 30 seconds); in fact, the post-shock duration of the VF zone is applied (short and non-programmable by 1 second) which leaves less time for spontaneous termination; similarly, therapies carry a risk (moderate as 8 electric shocks can be delivered for the same VF episode) that the device exhausts all therapies and a new episode is not treated

Episode Classification	Ventricular End-of-Episode Timer (elapsed time required to declare episode over)
Nontreated (no therapy delivered)	10 seconds
Treated (only ATP therapy delivered)	10 seconds
Treated (any shock therapy delivered)	30 seconds

This figure shows the various (non-programmable) timers used to define the end of the episode; after an electric shock, the end-of-episode marker appears if, after 30 seconds, criterion 8/10 has not been verified.

References to know

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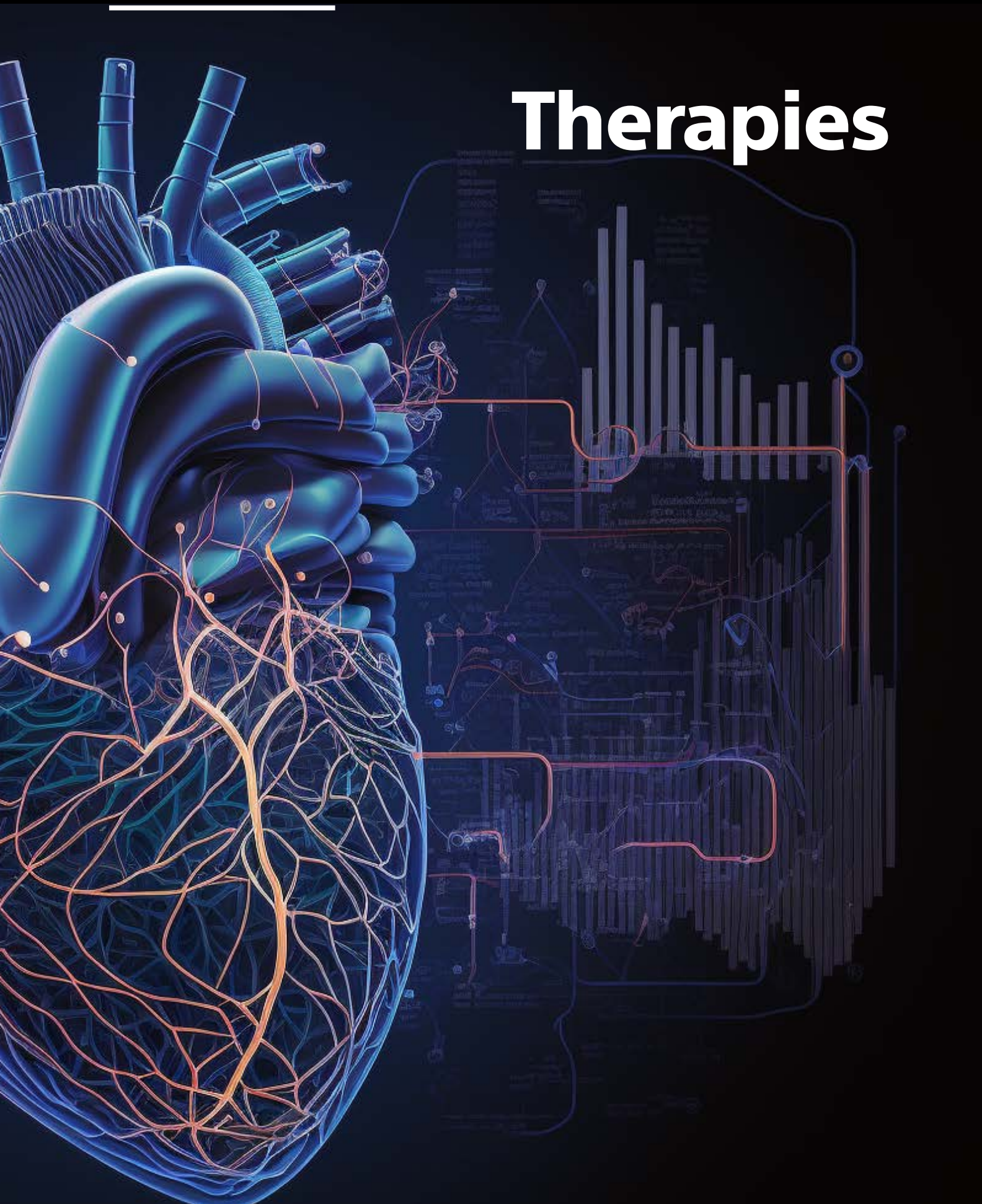
these 2 meta-analyses show that increasing the number of cycles in initial detection provides a benefit in terms of reducing appropriate and inappropriate therapies and leads to a significant benefit in terms of mortality

Chapter 2

Therapies



1 VF episode correctly detected and treated with maximum output shock

Patient

- 57-year-old male with ischemic cardiomyopathy; implanted with a Resonate triple-chamber defibrillator

Summary

- episode classified in the VF zone
- 41 Joule shock with a charge time of approximately 9 seconds
- shock impedance of 54 Ohms

EGM layout

1. sinus rhythm and biventricular pacing (AS, RVP-LVP)
2. spontaneous, very rapid, polymorphic ventricular arrhythmia; first cycle classified as VT, subsequent cycles as VF
3. V-Epsd marker (criterion 8/10 met); criterion fulfilled for VT zone (1 cycle in VT zone + 7 cycles in VF zone); initial detection duration for the VT zone starts on this beat
4. on this cycle, the initial detection window is satisfied for the VF zone (8 cycles in the VF zone); the initial detection duration for the VF zone begins on this beat; the VF zone duration takes precedence over the VT zone duration; even if the VT zone duration ends before the VF zone duration, if the 6/10 criterion is satisfied for the VF zone, VT zone therapies are suspended until the VF zone duration ends.
5. persistence of arrhythmia in the VF zone for the initial duration of 5 seconds in the VF zone (V-Detect)
6. start of capacitor charging

7 ventricular sensing remains adequate during charging, with the exception of a few under-sensed cycles which explain the RVS markers; these undersensed events are too far apart to cause charge diversion.

8 end of charge; the charge lasted approximately 9 seconds, with the amplitude of the shock delivered corresponding to the maximum capacity of the device

9 a refractory period of 135 ms begins at the end of the charge; the first cycle following this refractory period is not counted (--); the 2 following cycles are fast (VF), the charge diversion window has elapsed (500 ms after the end of the charge); criterion 2/3 met.

10 41 Joule shock delivered on the second cycle (synchronized with the R wave)

11 the first atrial cycle following the post-shock refractory period (500 ms) is not counted (--)

12 in the absence of spontaneous ventricular activity, ventricular pacing occurs 2 seconds after the shock

13 effective shock and arrhythmia termination

LATITUDE™ Patient Management - Event Detail Report	Report Created: 16 Jan 2023

Boston Scientific

Date of Birth:
Device: **RESONATE CRT-D G424/490880**
Clinic:
Search Tags:
Tachy Mode: **Monitor + Therapy**

Latest Device Transmission: **15 Jun 2021 03:22 CEST**
Last Office Interrogation: **19 May 2021**
Implant Date:

V-42: 20 Apr 2021 00:54, VF, A Rate: 64 min^{-1}, V Rate: 321 min^{-1}

Detail

VF Event Onset

Avg A Rate	64 min^{-1}
Avg V Rate	321 min^{-1}
Detection	Rhythm ID
Template	13 Apr 2021 18:29
RhythmMatch™ Threshold	94 %

At V-Detect

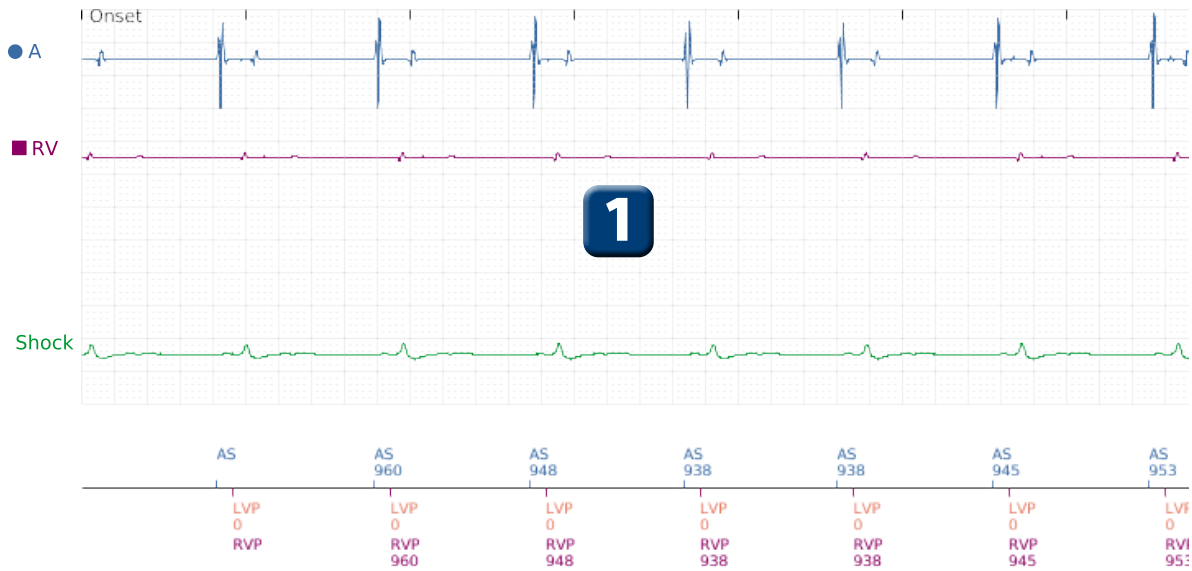
Avg A Rate	65 min^{-1}
Avg V Rate	297 min^{-1}
Rate Zone	VF
Stability	(19 ms, Off)
V>A Rate	(True, Off)
AFib	(False, Off)
RhythmID Correlated	False
RhythmMatch™	Too Fast
SRD Met	(False, Off)
ATP Timeout	False

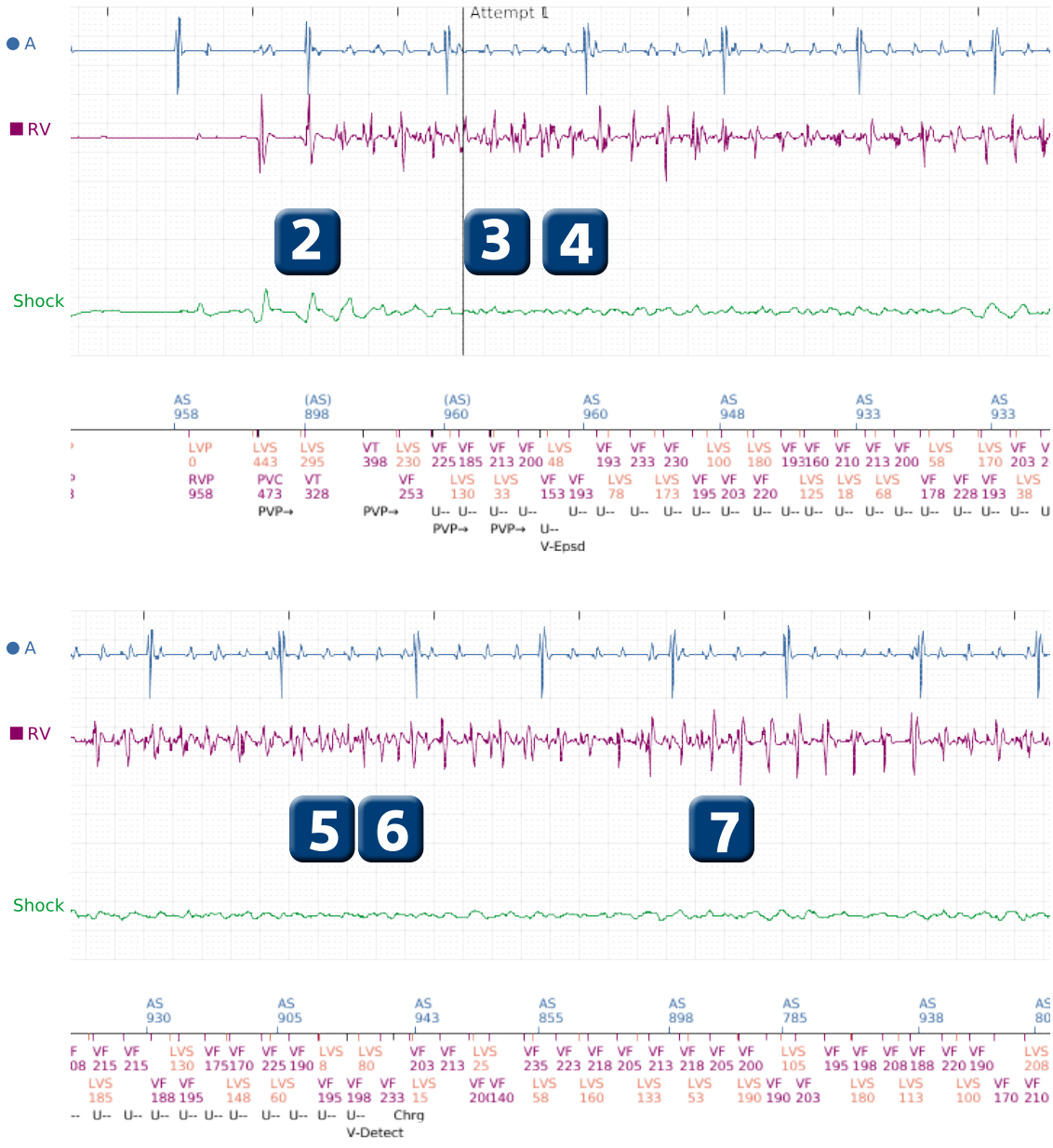
Attempt 1, 41 J V Shock

Elapsed Time	00:00:06
Shock Information	
Charge Time	9.8 s
Lead Impedance	76 Ω
Lead Polarity	Initial

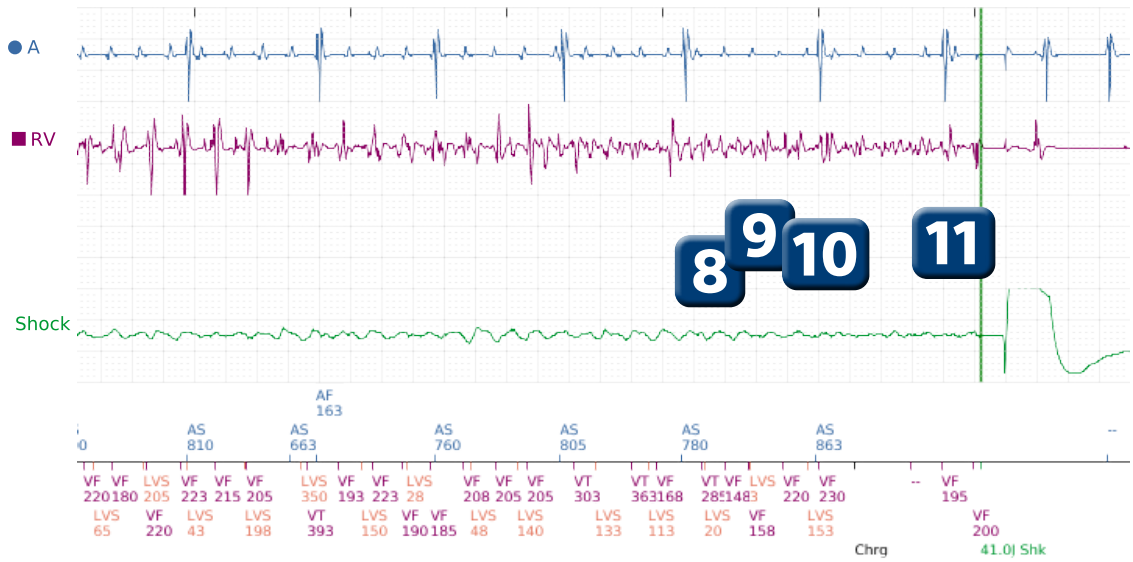
Event Ended 00:00:47

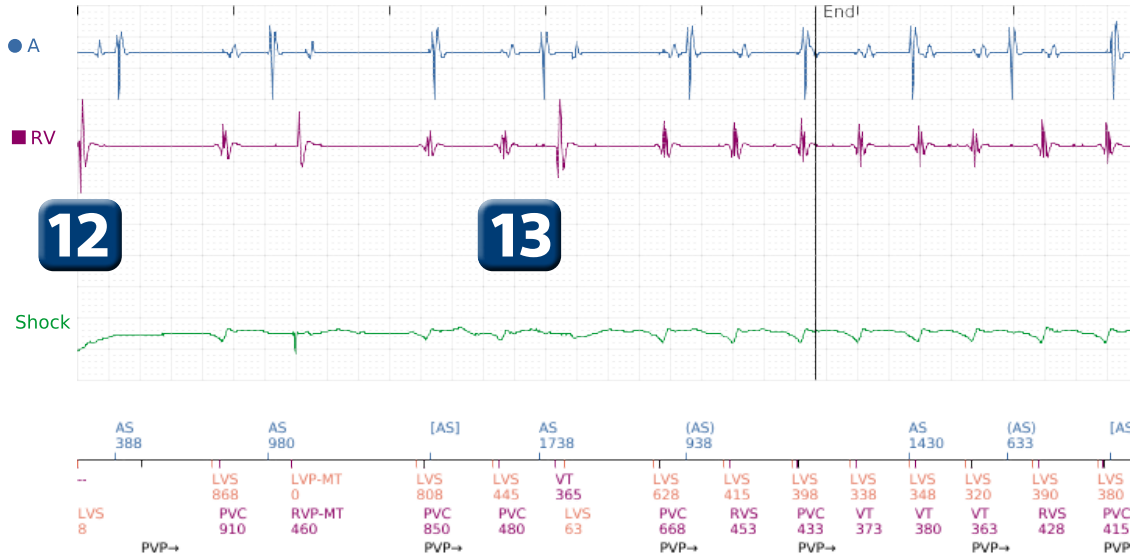
EGM displayed at 25mm per second

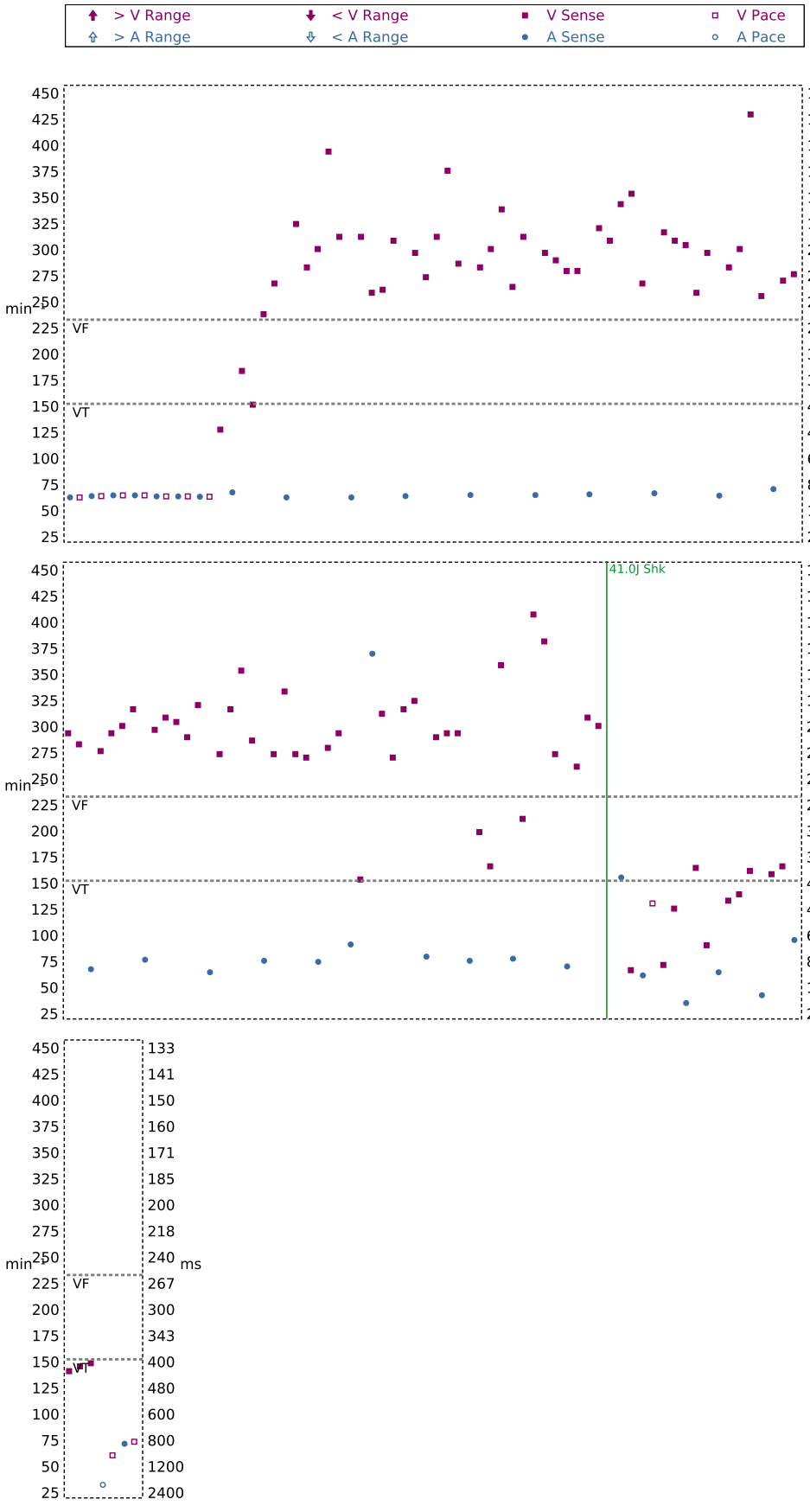



Attempt 1
A
RV
Shock
2
3
4
5
6
7
AS 958
(AS) 898
(AS) 960
AS 960
AS 948
AS 933
AS 933
AS 930
AS 905
AS 943
AS 855
AS 898
AS 785
AS 938
PVP→
V-Epsd
V-Detect
Chrg

LATITUDE™ Patient Management - Event Detail Report 16 Jan 2023





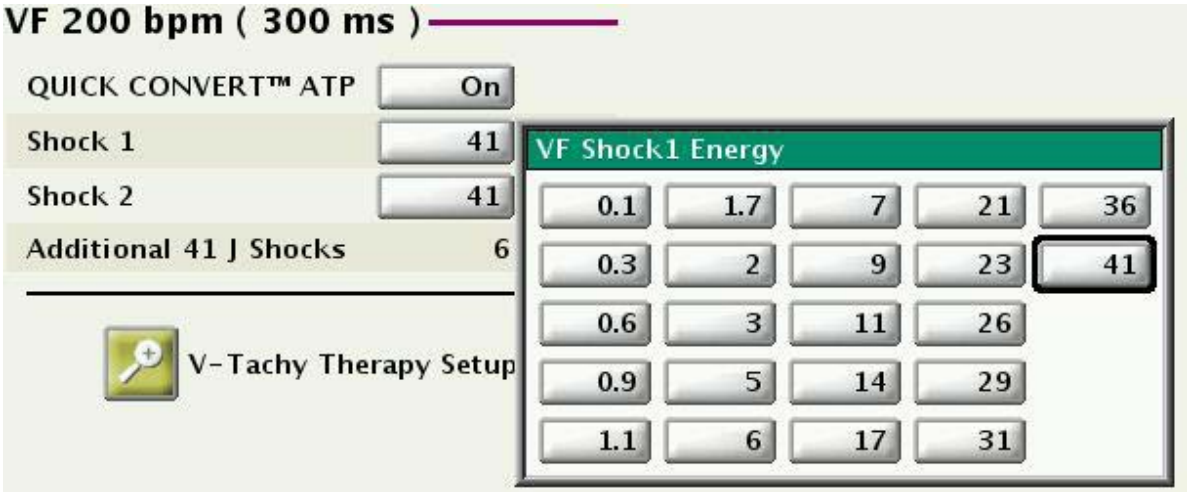

> V Range
< V Range
V Sense
V Pace
> A Range
< A Range
A Sense
A Pace
min
ms
VF
VT
41.0J Shk

Points to remember

- implantable defibrillators were historically developed to prevent the risk of sudden death and terminate malignant ventricular arrhythmia via a shock
- this tracing illustrates normal defibrillator operation during a VF episode: correct arrhythmia detection, capacitor charging, confirmation at the end of charge and effective shock
- the arrhythmia is immediately extremely rapid, polymorphic and disorganized, consistent with VF; any attempt to terminate this type of arrhythmia by anti-tachycardia pacing is doomed to fail, and a shock remains the standard therapy in this setting
- detection is correct and there is no discrimination of arrhythmia origin in this ventricular rate range
- for a Boston Scientific defibrillator, a series of 8 shocks can be programmed in the VF zone
- the amplitude of shocks 3 to 8 is not programmable and is always the maximum (41 Joules)
- the amplitude of the first 2 shocks is programmable, even though the amplitude of the second shock must be at least equal to that of the first; the amplitude of the second shock is generally programmed at the device's maximum capacity
- the amplitude of the first shock can either be programmed to the maximum capacity of the device, or to a lower value of 10 to 20 Joules; programming a first shock of intermediate amplitude makes it possible to reduce the charge time and the delay between arrhythmia onset and shock delivery, and may in certain specific cases reduce the risk of loss of consciousness; the choice of the amplitude of the first

shock in the VF zone therefore represents a compromise: medium energy may be enough to terminate VF after a short charge time, but if this fails, the second, maximum-energy shock is delivered after a long total duration in VF; maximum energy is more effective from the outset, but at the cost of a longer initial charge time

- international recommendations state that it is reasonable (class IIA recommendation) to program the maximum amplitude in VF zones from the outset, unless an induction test has shown efficacy at a lower amplitude.



This figure shows the various programming options for the amplitude of the first shock in the VF zone; the amplitude of the second shock is also programmable but must be at least equal to that of the first; the amplitude of shocks 3-8 is necessarily maximum (41 joules; in the VF zone, 8 shocks can be delivered).

2 VF episode with low-amplitude shock in a child

Patient

- 13-year-old child successfully resuscitated following sudden cardiac arrest; implanted with an Incepta single-chamber defibrillator; multiple episodes of VF following implantation

Summary

- episode classified in the VF zone
- Shock of 14 Joules with a charge time of 2.7 seconds
- 33 Ohms shock impedance

EGM layout

1. sinus rhythm (VS)
2. spontaneous ventricular arrhythmia, very rapid, polymorphic; all cycles are classified in the VF zone
3. V-Epsd marker (criterion 8/10 met) for VF zone (8 cycles in the VF zone); start of initial duration (programmed to 1 second)
4. end of duration and start of capacitor charging
5. end of charge; this charge lasted 2.7 seconds
6. a refractory period of 135 ms begins at the end of the charge; the first cycle following this refractory period is not counted (--); the 2 cycles that follow are fast (VF and VT); the charge diversion window is over (500 ms after the end of the charge); criterion 2/3 met.
7. 14 Joule electric shock delivered on the second cycle (synchronized with the R wave)
8. effective shock and arrhythmia termination

Gestionnaire de patients LATITUDE™ - Détail de l'événement	Rapport créé : 23 févr. 2023

Boston Scientific

Date de naissance :
Appareil : **INCEPTA ICD F161**
Centre :
Critères de recherche :
Mode Tachy : **Surveill. + Trait.**

Dernière transmission du dispositif : **09 févr. 2023 17:53 CET**
Dernière interrogation au cabinet : **08 sept. 2021**
Date d'implantation :
Groupe de patients :

V-35: 18 oct. 2019 07:28, FV, Fréquence V : 245 min^{-1}

Détail

FV Début événem.

Fréq. V moy.	245 min^{-1}
Détection	Fréq. Uniq.
Référence	18 oct. 2019 05:40

Lors de la Détect-V

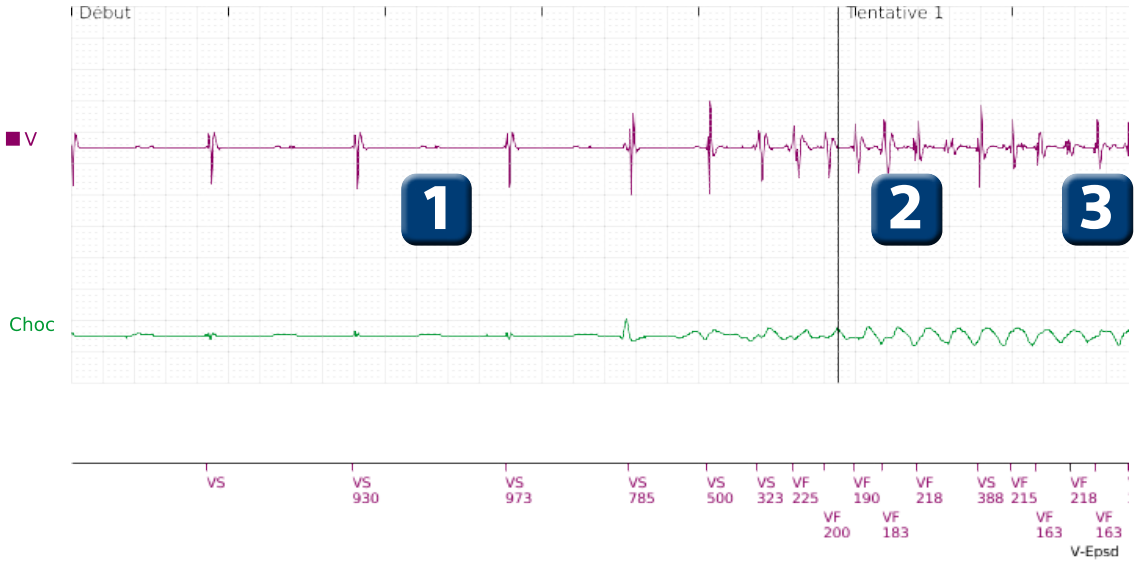
Fréq. V moy.	261 min^{-1}
Zone de fréquence	FV
RhythmID corrélé	Faux
RhythmMatch™	Trop rapide
DFS satisfaite	(Faux, arrêt)
Durée limite ATP	Faux

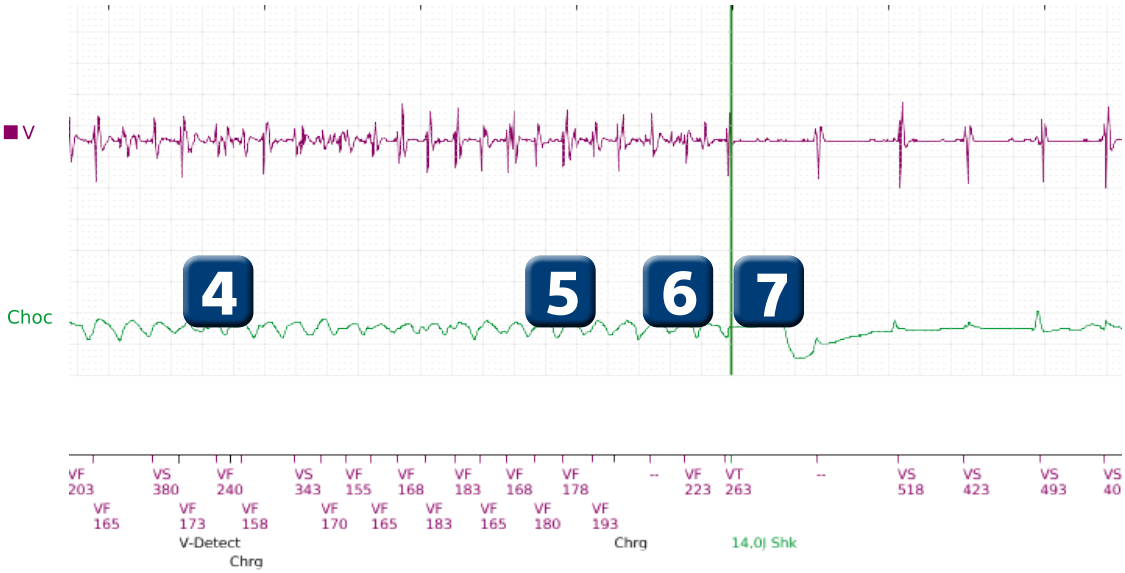
Tentative 1, 14 J Choc V

Temps écoulé	00:00:03
Informations sur le choc	
Durée de charge	2,7 s
Impédance de la sonde	33 Ω
Polarité de la sonde	Initial

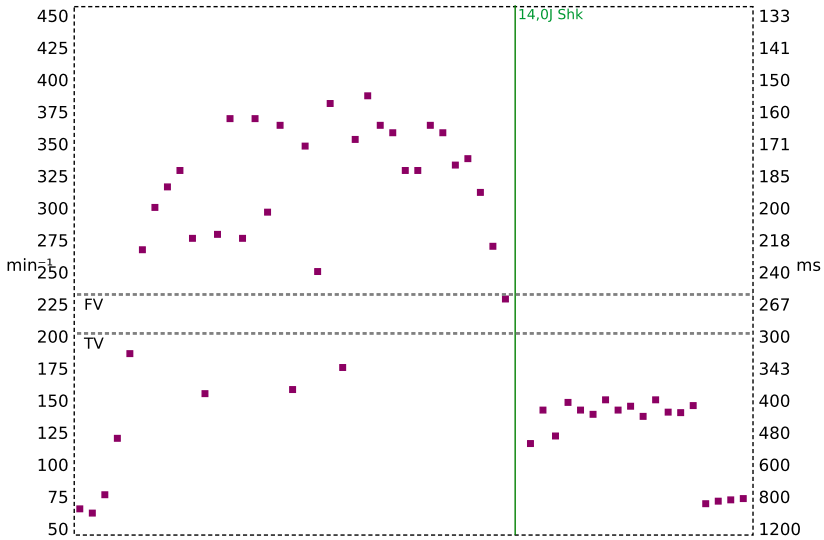
Fin de l'événement 00:00:37

EGM affiché à 25 mm par seconde




V
Choc
4
5
6
7
VF 203
VS 380
VF 240
VS 343
VF 155
VF 168
VF 183
VF 168
VF 178
-- 223
VF 263
VT
-- 518
VS 423
VS 493
VS 40
VF 165
VF 173
VF 158
V-Detect
Chrg
VF 170
VF 165
VF 183
VF 165
VF 180
VF 193
Chrg
14,0J Shk

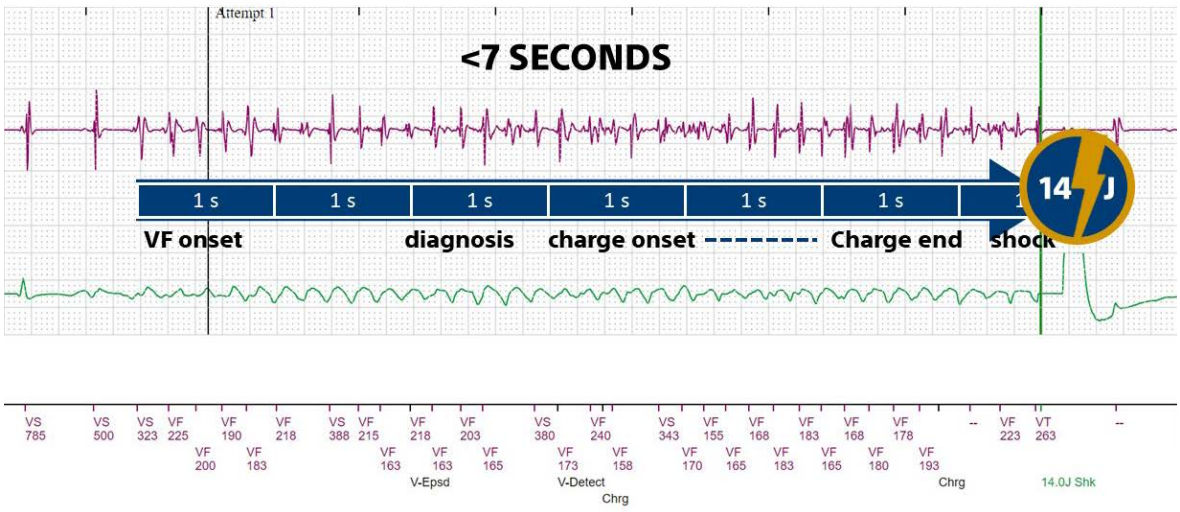

Fin
V
Choc
8
> Plage V
< Plage V
Détection V
Stimulati
5
VS 423
VS 433
VS 400
VS 423
VS 415
VS 438
VS 400
VS 428
VS 430
VS 413
VS 865
VS 840
VS 83


14,0J Shk
min-1
ms
FV
TV
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
133
141
150
160
171
185
200
218
240
267
300
343
400
480
600
800
1200

Points to remember

- children implanted with a defibrillator are very much a minority compared to adults (less than 1% of defibrillator wearers are children)
- the indications for defibrillation in pediatrics have not been the subject of randomized studies and are based on expert consensus; although initially reserved for secondary prevention indications, the percentage of implantations in primary prevention has now increased considerably
- there are no devices or leads specific to this age group that have been adapted to children's anatomical characteristics
- the risk of inappropriate therapies is increased in children due to a higher risk of lead fracture as children grow and subject leads to greater stress; higher baseline heart rates and frequent episodes of sinus tachycardia, supraventricular tachycardia or T-wave oversensing also contribute
- there is no standardized programming and the various parameters having to be adjusted and optimized on a case-by-case basis; in secondary prevention of resuscitated sudden cardiac death, a single VF zone is usually programmed with a relatively high minimum rate, higher than the heart rate range corresponding to sinus tachycardia; to reduce the risk of inappropriate therapies, it's customary to program relatively long initial durations, as arrhythmia is generally well tolerated in children, even for high ventricular rates, and syncope is usually relatively delayed

- the programming in this young patient may seem surprising, with an initial duration in the VF zone of 1 second; this patient initially presented with traumatic syncope and to avoid future falls, a decision was made to deliver the shock before loss of consciousness; the interval between the onset of arrhythmia and the shock was around 6 seconds (approx. 2 seconds for the 8 initial cycles, initial duration of 1 second, charge time of 2.7 seconds, diversion window of 500 ms)
- in children, the amplitude of the first shock is generally programmed to be relatively low (sometimes 2 to 5 Joules in neonates); an amplitude of 1 Joule/kg provides high efficacy with limited deleterious effect
- telemonitoring is essential to reduce inappropriate therapies in children (as in adults ...).



This figure shows the time interval in this young patient between the onset of arrhythmia and the moment when the shock is delivered; this interval is broken down into 8/10 criteria, initial duration in the VF zone, capacitor charging, confirmation at the end of charging, etc.

3 Multiple electric shocks in the VF zone

Patient

- 75-year-old male with ischemic cardiomyopathy; implanted with a Resonate triple-chamber defibrillator

Summary

- episode classified in the VF zone
- 5 maximum amplitude shocks

EGM layout

1 possible slow VT

2 acceleration of arrhythmia into the VF zone

3 end of duration and start of capacitor charging

4 arrhythmia degenerates into VF (very rapid, disorganized ventricular activity)

5 end of charge and 41 Joule electric shock delivered on the second fast cycle (synchronized to the R wave)

6 reinitiation of an organized arrhythmia

7 redetection criterion 8/10 verified (start of redetection time for VF zone)

8 end of 1 second duration and charging of capacitors

9 shock delivered at end of charge after the 500 ms post-shock window (no need to validate the 2/3 rapid cycle criterion)

10 reinitiation of ventricular arrhythmia

11 redetection criterion 8/10 verified (start of redetection time for VF zone)

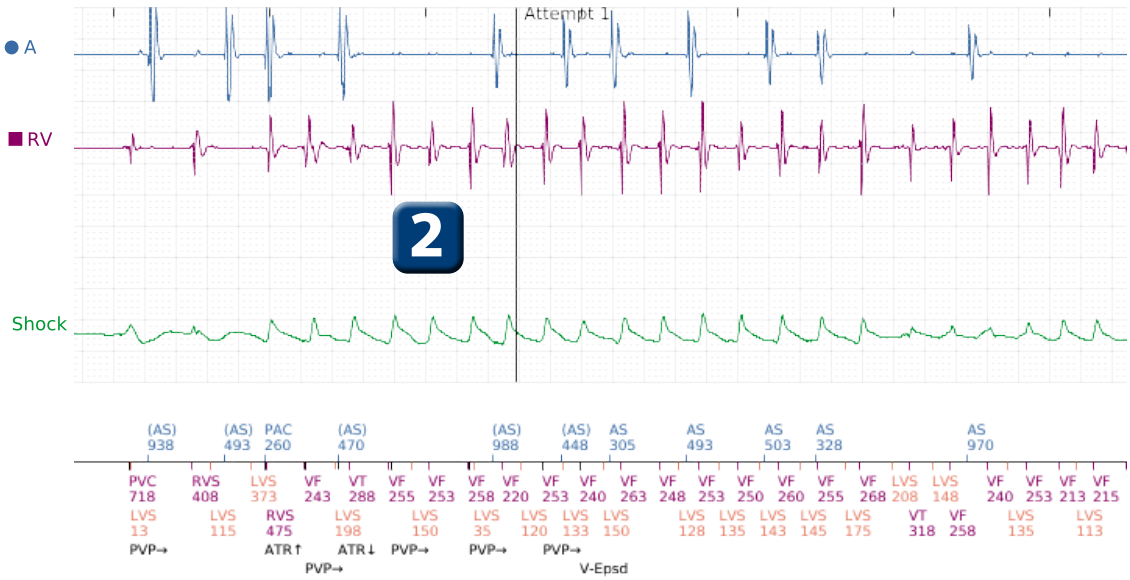
12 end of 1 second duration and charging of capacitors

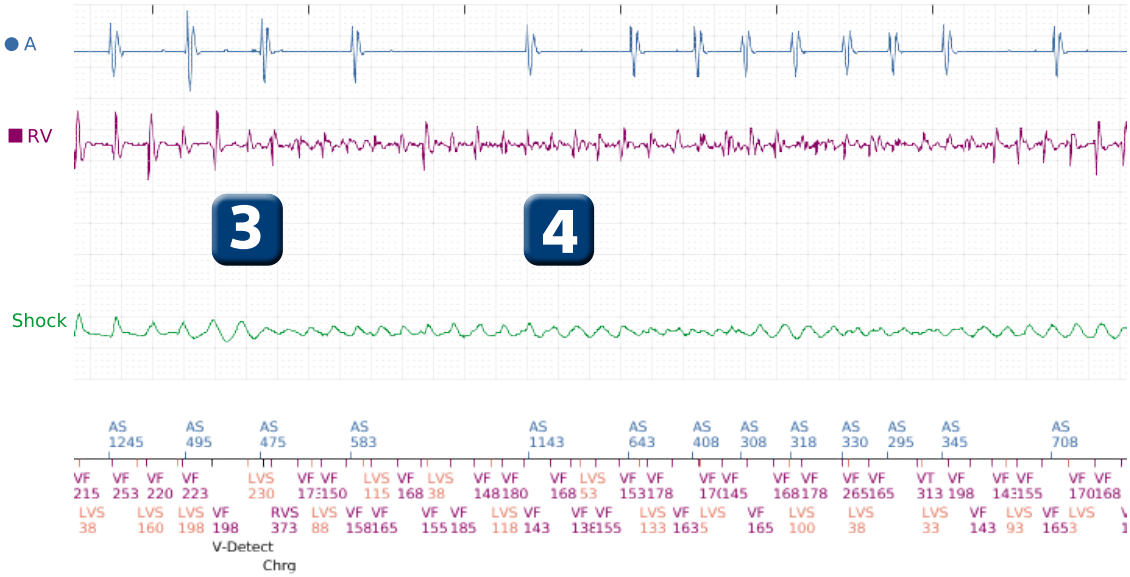
13 shock delivered at end of charge after 500 ms post-shock window (no need to validate the 2/3 rapid cycle criterion)

14 fourth shock

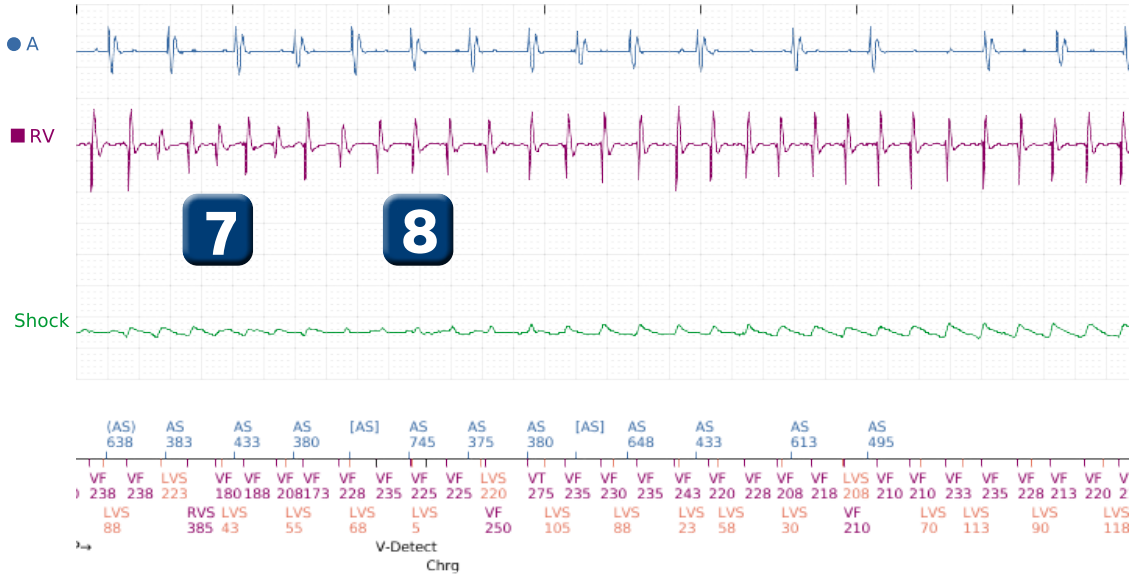
15 fifth shock

16 arrhythmia terminatio

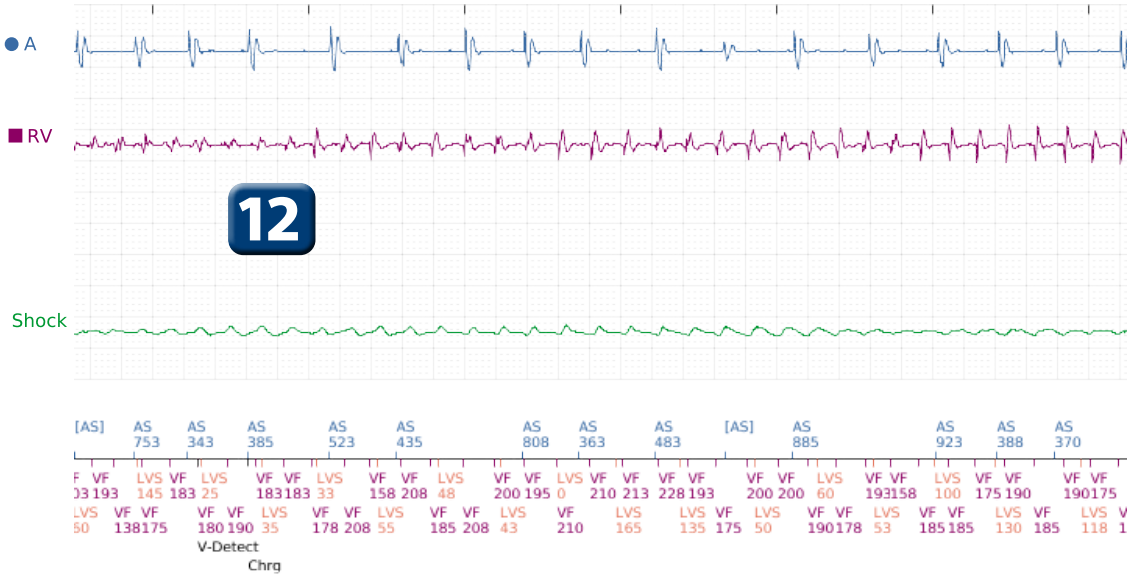

Attempt 1
A
RV
Shock
2
(AS) 938
(AS) 493
PAC 260
(AS) 470
(AS) 988
(AS) 448
AS 305
AS 493
AS 503
AS 328
AS 970
PVP→
ATR↑
ATR↓
V-Epsd

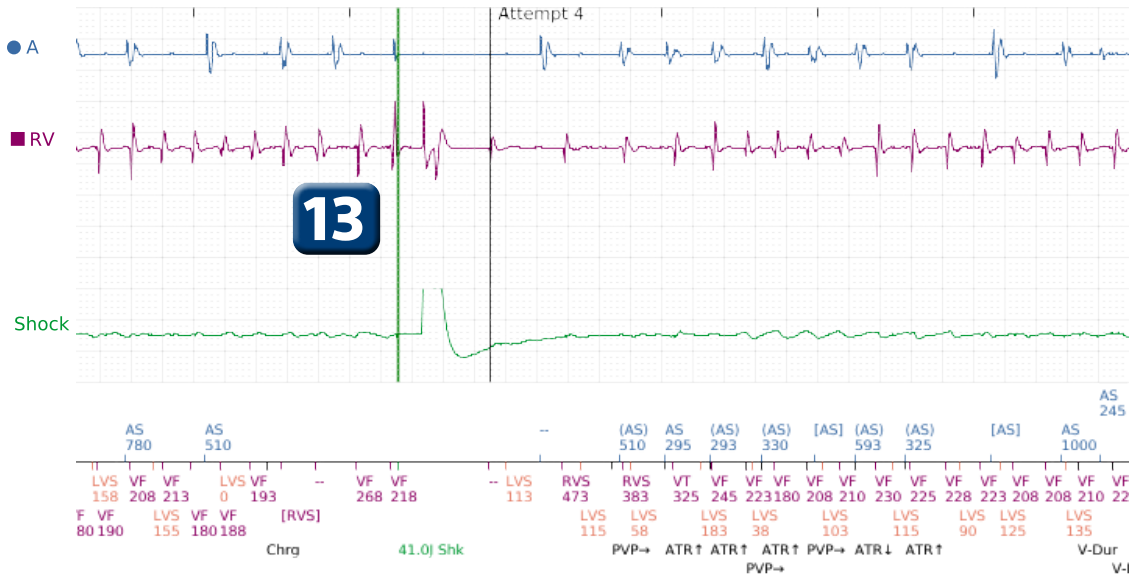

A
RV
Shock
3
4
AS 1245
AS 495
AS 475
AS 583
AS 1143
AS 643
AS 408
AS 308
AS 318
AS 330
AS 295
AS 345
AS 708
V-Detect
Chrg

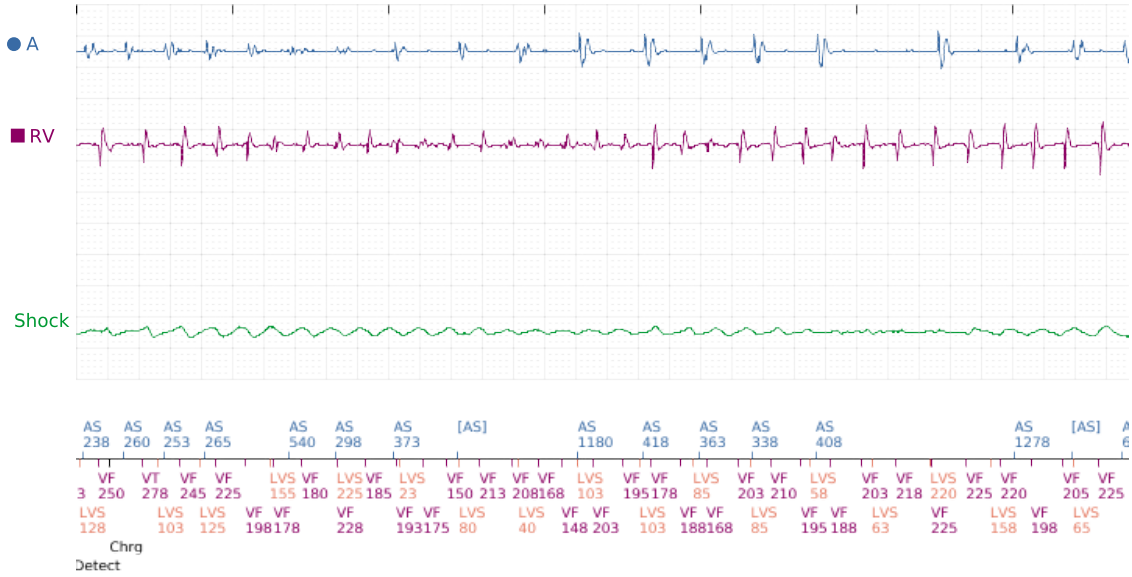

A
RV
Shock
Attempt 2
5
6
Chrg
41.0J Shk
PVP→
PVP→

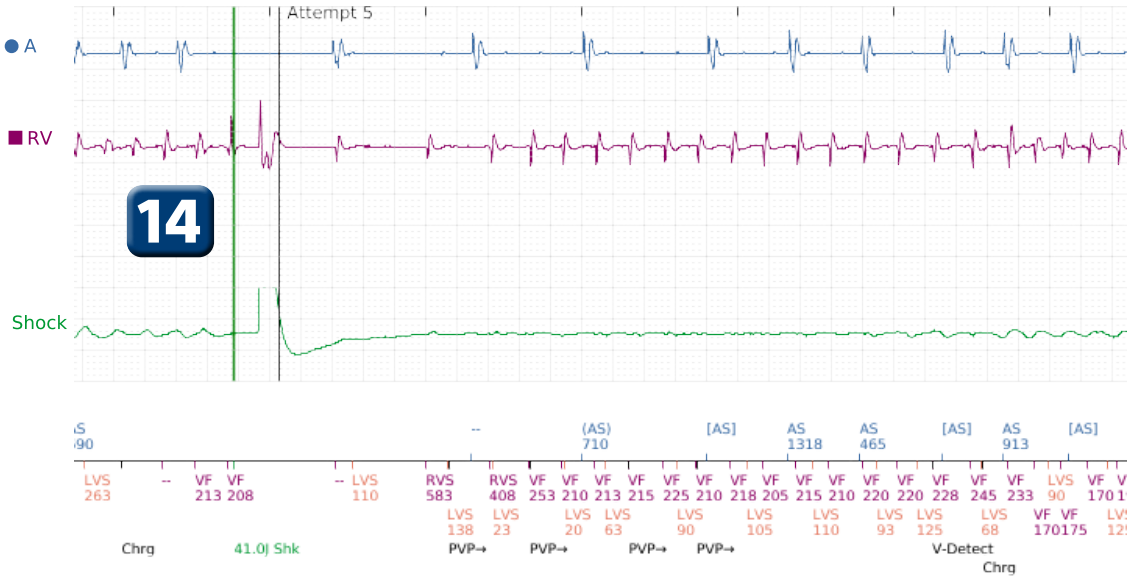

A
RV
Shock
7
8
V-Detect
Chrg

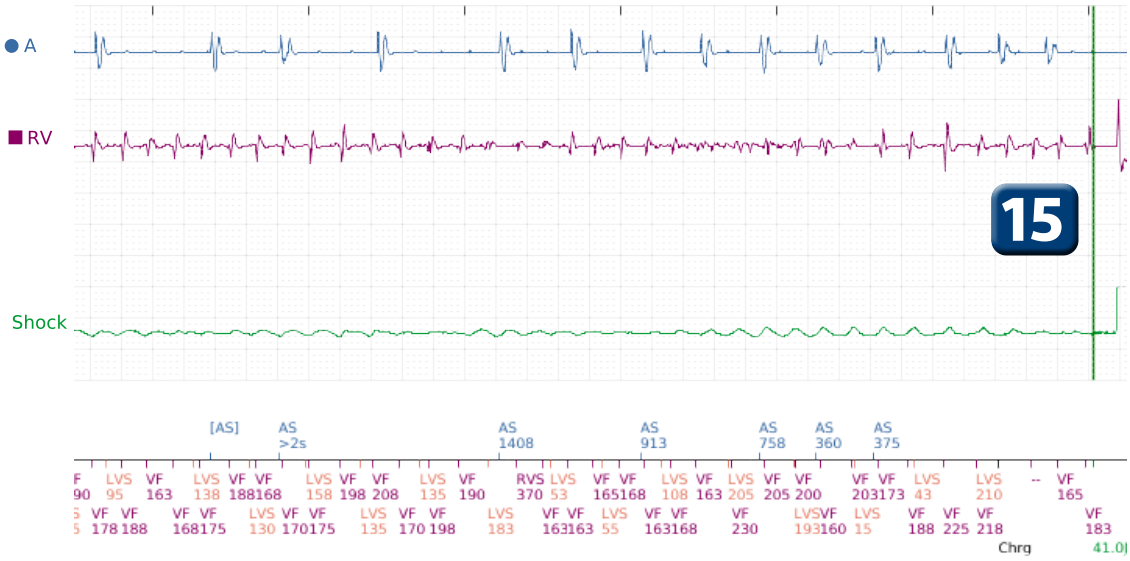

A
RV
Shock
Attempt 3
9
10
11
Chrg
41.0J Shk
PVP→

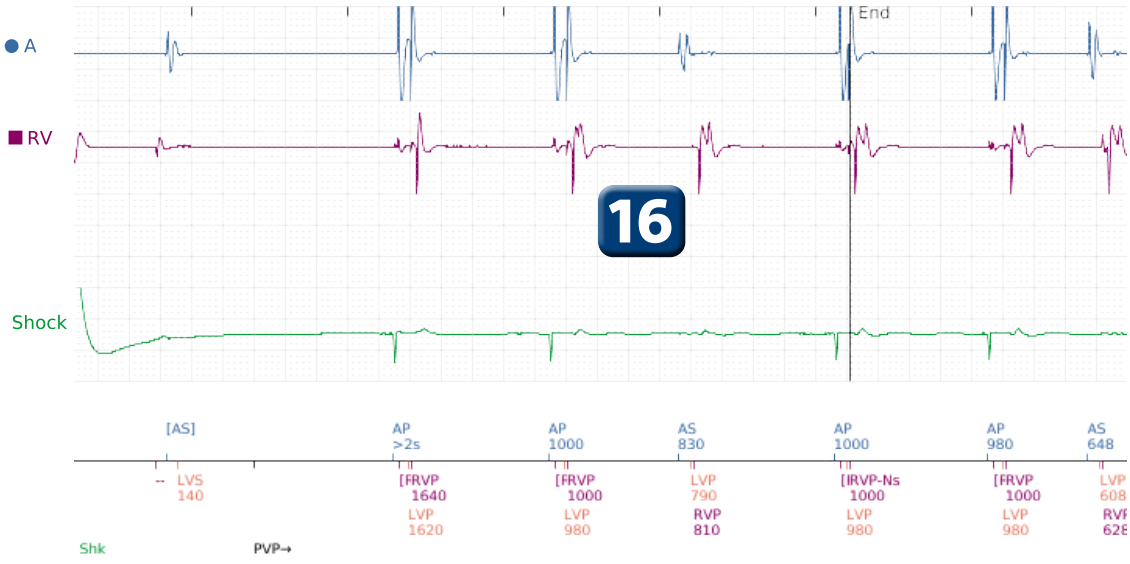

A
RV
Shock
12
V-Detect
Chrg

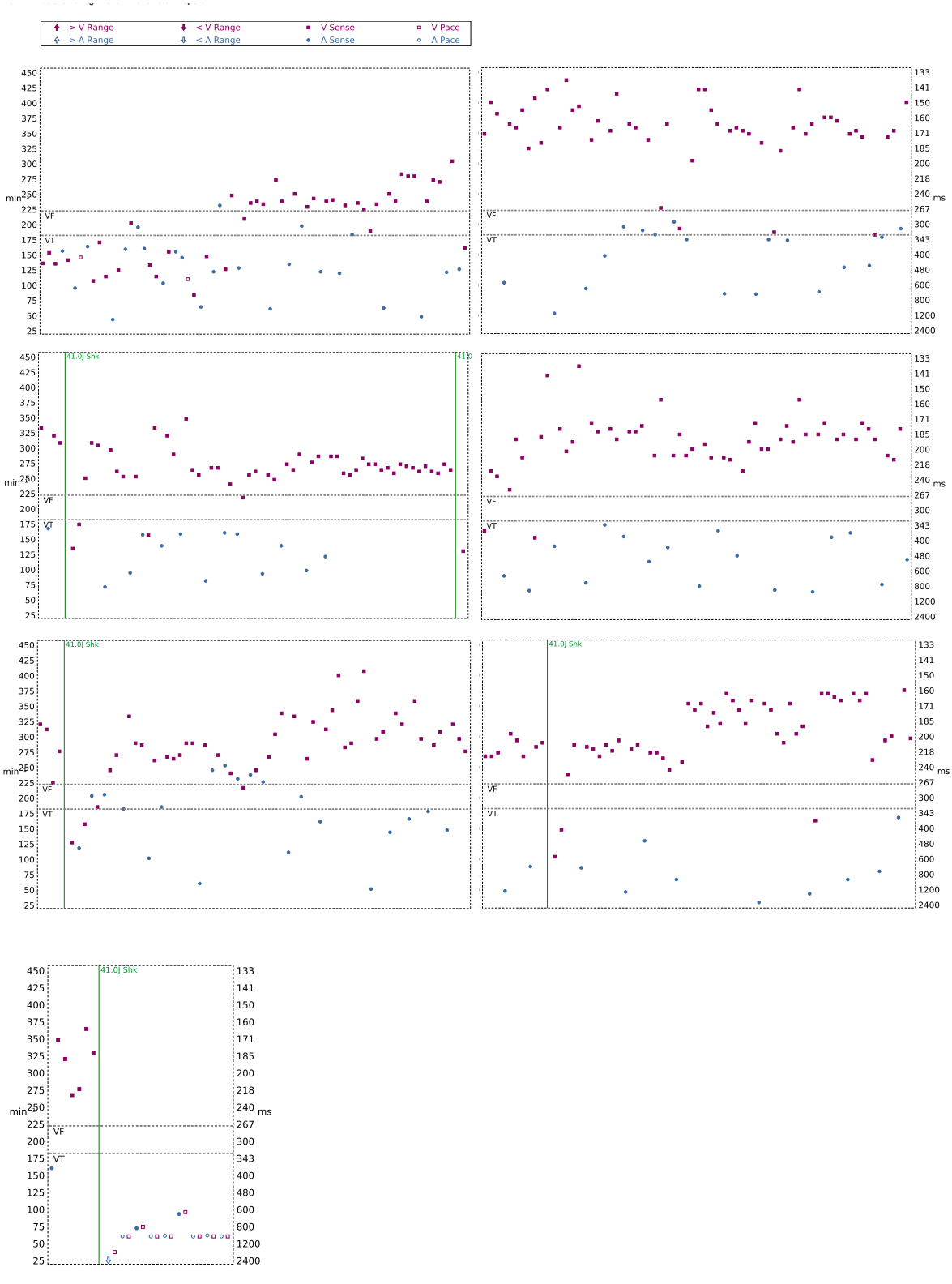

Attempt 4
A
RV
13
Shock
Chrg
41.0J Shk


A
RV
Shock
Chrg
Detect


Attempt 5
A
RV
14
Shock
Chrg
41.0J Shk
PVP→
V-Detect
Chrg


A
RV
15
Shock
Chrg


End
A
RV
16
Shock
Shk
PVP→


> V Range
< V Range
V Sense
V Pace
> A Range
< A Range
A Sense
A Pace
min
ms
VF
VT
41.0J Shk

41.0J Shk
min
ms
VF
VT

Points to remember

- the patient has a high defibrillation threshold, and five shocks are required to permanently disrupt the VF episode
- even though technological advances have significantly improved a defibrillator's ability to terminate VF episodes (95% of patients now have a sufficient safety margin), an increase in the number of patients implanted necessarily increases the number of patients with a high threshold.
- the existence of a high defibrillation threshold is the result of a complex interaction between molecular, electrical, mechanical, anatomical, neurohumoral or pharmacological factors
- all initial major studies demonstrating a beneficial effect to defibrillator implantation for improving survival, included in their protocols a defibrillation test at the time of implantation to verify proper device function
- following the results of randomized trials, defibrillation threshold assessment at the end of implantation is no longer routinely performed; however, the presence of specific risk factors may result in this test being performed in certain patients suspected of having an insufficient safety margin (right-sided implantation, suspicion of lead dysfunction, atypical position of the defibrillation lead, patient on amiodarone, obese patient, etc.).
- the detection of an elevated defibrillation threshold during a spontaneous episode of VF constitutes an absolute emergency, and should lead to management aimed at 1) reducing the risk of arrhythmia recurrence, 2) identifying reversible causes (hypomagnesemia, hypocalcemia, hyperkalemia, acidosis, pneumothorax, pleural effusion, tamponade...) contributing to the increased threshold, and 3) optimizing the defibrillation circuit (lead position, box, number of coils available, programmable parameters, etc.).
- to optimize shock wave characteristics, some parameters are programmable, while

others are not, depending on the manufacturer; in a Boston Scientific defibrillator, shock amplitude, vector and polarity are programmable.

- the key parameters for successful defibrillation are the voltage and duration of shock delivery; shock impedance corresponds to the sum of the forces opposing defibrillation current output in the box-lead-myocardial tissue circuit; increased impedance limits the amount of energy delivered and helps raise the defibrillation threshold
- in a monophasic shock, the polarity of each electrode does not vary during the shock, whereas it reverses when the shock is biphasic; the shape of the shock wave is necessarily biphasic for a Boston Scientific defibrillator; the first phase of a biphasic shock is equivalent to that of a monophasic shock, albeit with less critical mass ; the second phase brings the membrane potential as close as possible to zero, to avoid reinduction of tachycardia or ventricular fibrillation; while early devices delivered monophasic shocks, the introduction of biphasic shocks on modern platforms has significantly reduced defibrillation thresholds and the risk of immediate reinduction
- tilt corresponds to the terminal voltage at which polarity is reversed during a biphasic shock and is not programmable for a Boston Scientific defibrillator (tilt 80%); phase 1 is truncated when the initial peak voltage has decreased by 60% (residual voltage 100%-60%=40%); phase 2 is truncated when the peak voltage (corresponding to the residual voltage of 40%) has decreased by 50% (40/2=20%); the pulse durations of the 2 phases are not programmable and are a consequence of tilt and shock impedance; the energy delivered is always lower than the energy charged (generally around 14% lower).
- the shock vector can be modified when the implanted lead is dual-coil; when the lead is single-coil, the only vector available is that between the right ventricular coil

and the can, the can always being active and an integral part of the defibrillation circuit; when the lead is a dual-coil lead, 3 options are programmable: single-coil (right ventricular coil - can), dual-coil (right ventricular coil - can + superior vena cava coil), cold can (right ventricular coil - superior vena cava coil).

- nominal shock polarity programming varies from one manufacturer to another; a meta-analysis suggested that a configuration using the right ventricular coil as the anode for the first phase (so-called anodic shock) enabled a certain number of patients to achieve a better defibrillation threshold than a cathodic shock (inverted configuration), with a lower risk of induction; for a Boston Scientific defibrillator, in nominal mode, the first shocks have a cathodic polarity (initial = RV coil as cathode during the first phase, then reversed for the second); the polarity of the last shock in the series is necessarily reversed compared with that of the 7 preceding shocks; it may therefore be desirable to reverse the polarity for the first shocks in this patient with a high threshold
- lead repositioning, implantation of a double-coil lead, addition of a coil in the azygos vein, coronary sinus or pericardial space may be options to modify the defibrillation vector

For a dual coil lead, there are 6 configuration options by varying the polarity and shock vector:

Vector

1. RV coil to RA coil and can: this vector is also known as vector V-TRIAD (double coil); the can serves as an active electrode («active can») in association with the double coil defibrillation lead; energy is delivered simultaneously from the distal coil to the proximal coil and from the distal coil to the can
2. RV coil to can: this vector also uses the can as an active electrode («active can», simple coil); energy is only delivered from the distal coil to the pulse generator can.

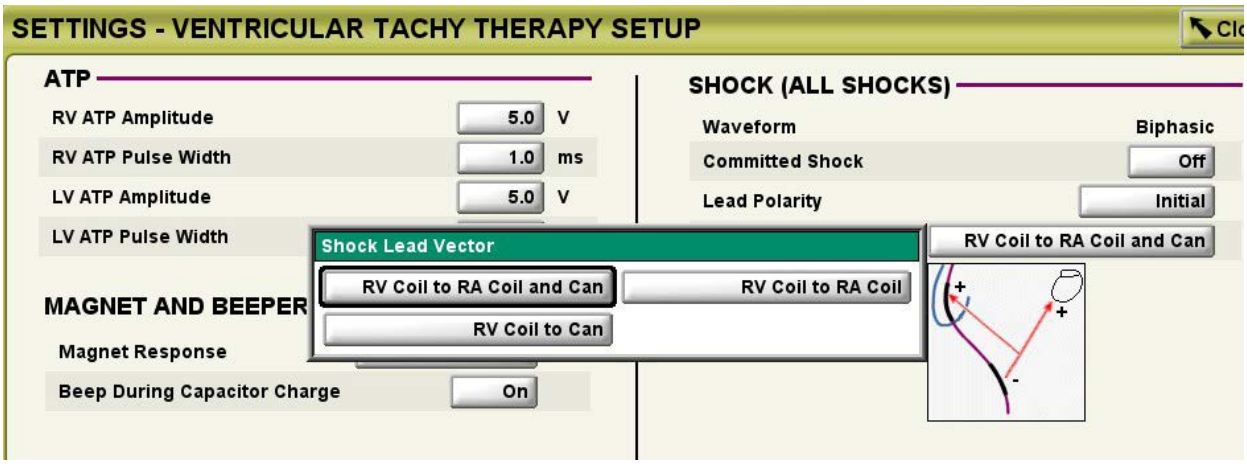
3 RV coil to RA coil: this vector, also known as the «cold can», cancels out the use of the box as an active electrode; energy is sent from the distal to the proximal coil.

Polarity

4 Initial polarity: the right ventricular coil is negative for the first phase (cathode), the casing and/or the superior vena cava coil are positive (anode); this corresponds to a cathodic shock.

5 Reversed polarity: the right ventricular coil is positive for the first phase (anode), while the casing and/or superior vena cava coil are negative (cathode); this corresponds to an anodic shock.

6 The RV coil to can configuration is the only effective configuration for a single-coil lead: the other 2 configurations must not be programmed; for the RV coil to RA coil configuration, no shock would be delivered; this vector must therefore never be used with a single-coil lead; when programmed, a warning window appears requesting verification that the lead is indeed double-coil.



4 VT in the VF zone and high defibrillation threshold

Patient

- 67-year-old man with ischemic cardiomyopathy; implanted with an Autogen dual-chamber defibrillator

Summary

- episode classified in the VF zone
- ATP in VF zone, then 4 shocks of maximum amplitude

EGM layout

1 organized arrhythmia in VT zone

2 8/10 criterion for VT zone; start of initial duration for TV zone

3 8/10 criterion for VF zone verified; start of initial duration for VF zone

4 end of VT zone duration, but initial VF zone duration still active

5 end of duration for VF zone

6 ATP Quick Convert

7 Ineffective ATP and capacitor charging

8 end of charge followed by shock delivery

9 after 2 slow cycles, onset of a very rapid disorganized ventricular arrhythmia detected in the VF zone

10 end of redetection time in VF zone (1 second, non-programmable) and capacitor charging

11 second shock

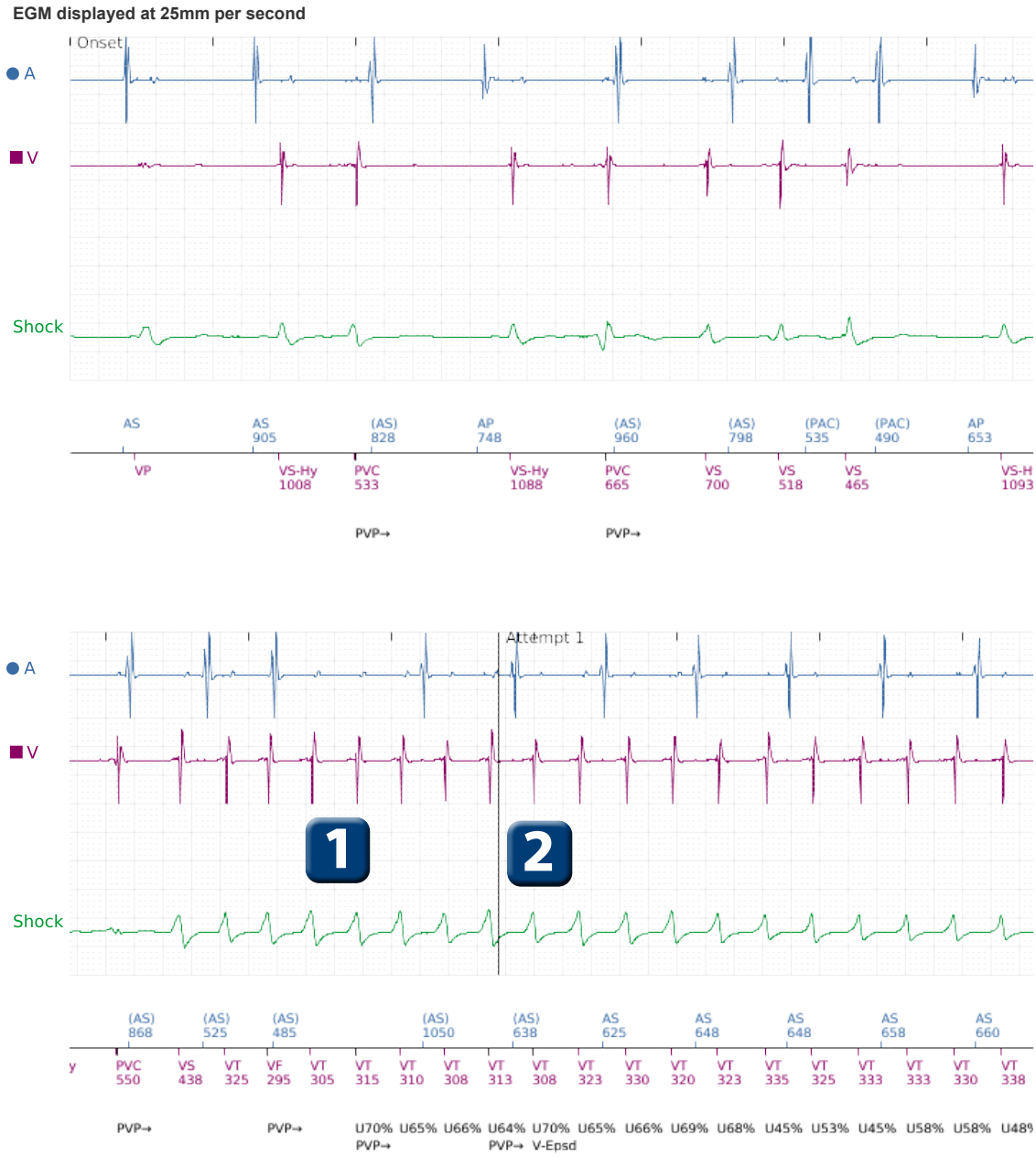
12 same sequence (shock, 2 slow cycles then VF reinitiation)

13 third shock

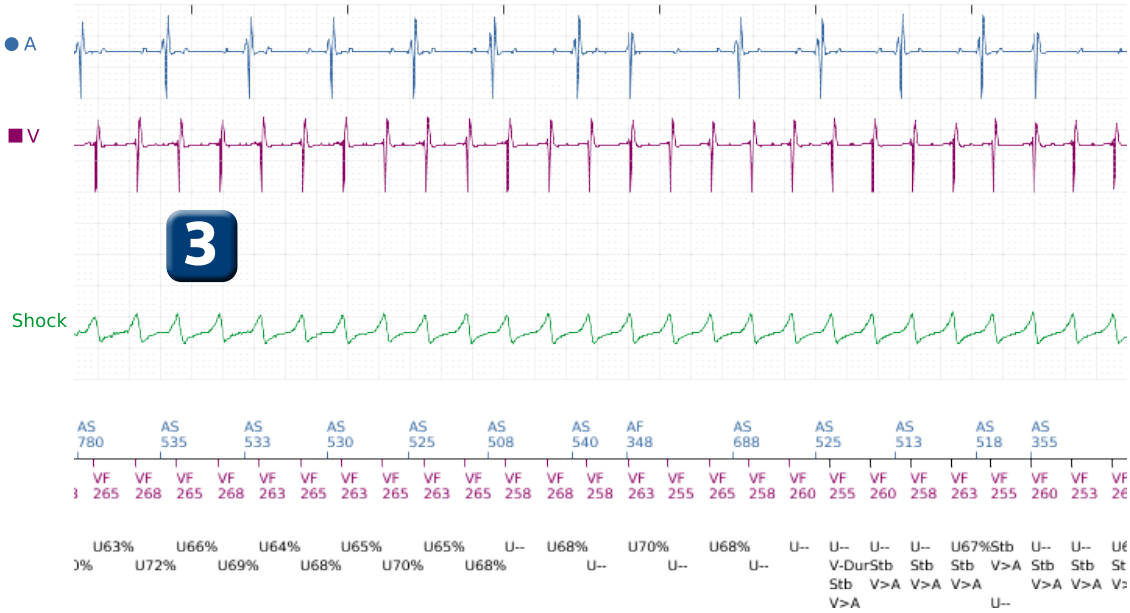
14 same sequence (shock, slow cycles, then reinitiation of VF)

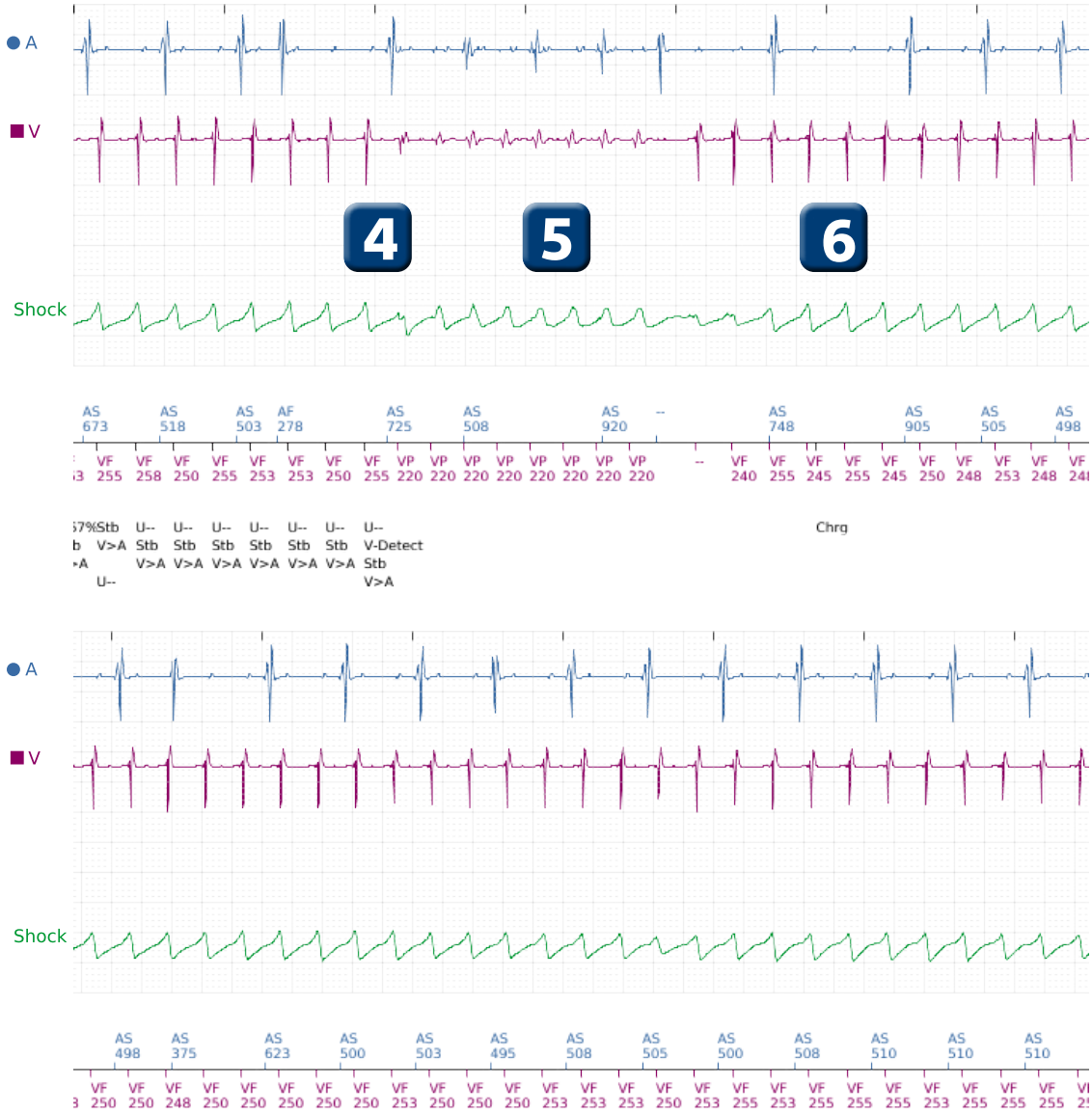
15 fourth shock

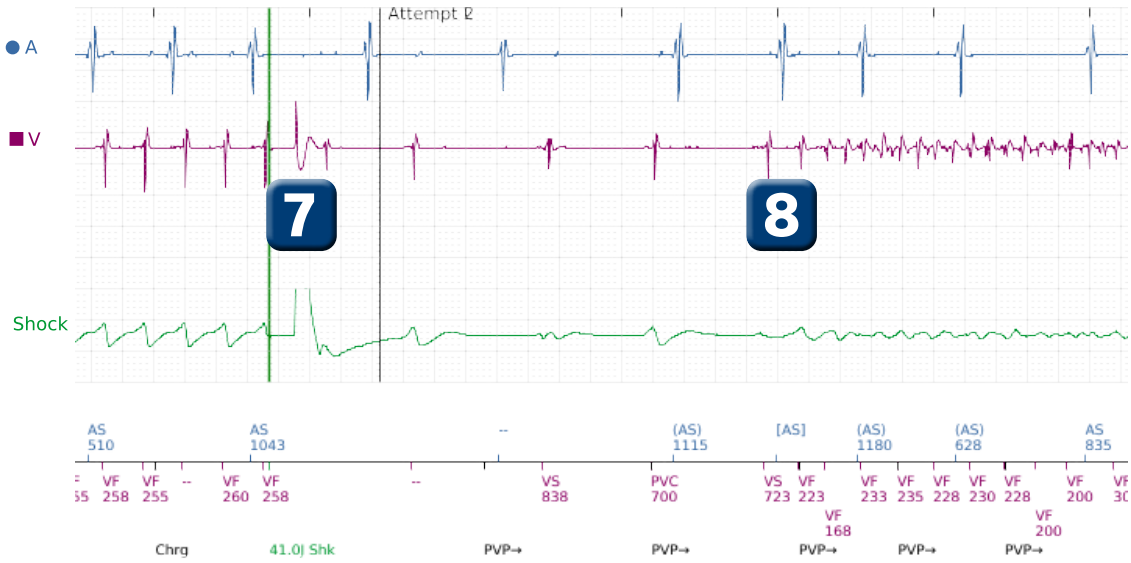
16 prolonged termination in VF (slow VT)




A
V
Shock
AS 668 AS 643 AS AS 643 AS 615 AS 628 AS 460 AS 518 AS 598 AS 590 AF 338
VT 325 VT 323 VT 315 VT 320 VT 320 VT VT 320 VT 318 VT 323 VT 318 VF 280 VS 358 VT 310 VT 310 VT 315 VF 295 VF 270 VT 303 VT 320 VF 273 VF 268 VF
U63% U58% U66% U64% U63% U65% U65% U60% U61% U70% U54% U67% U65% U61% U67% U66% U64% U52% U67% U65%

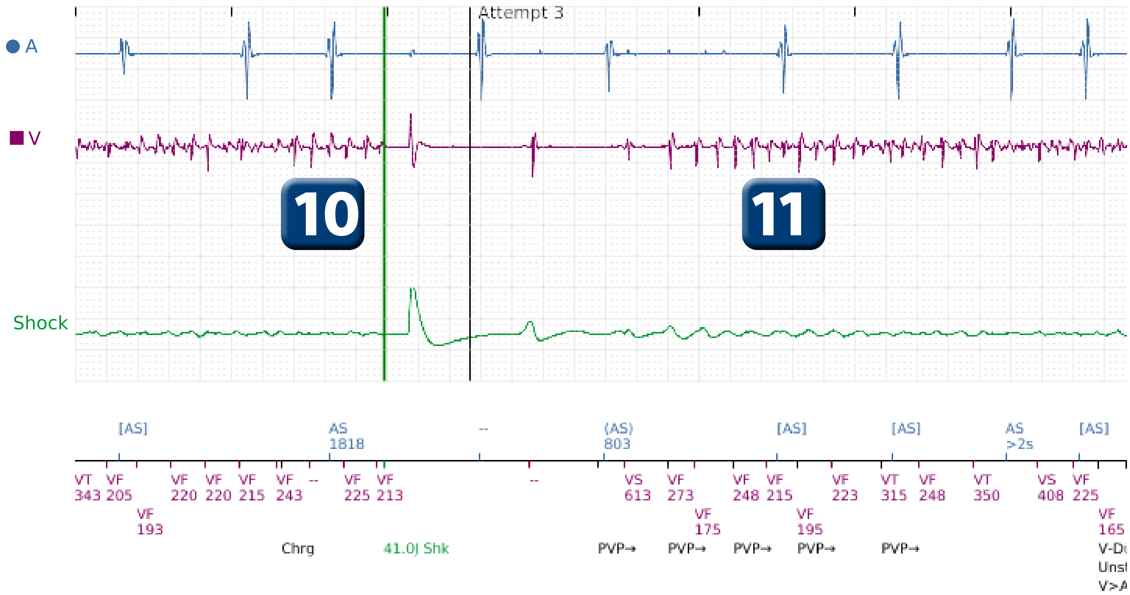

A
V
3
Shock
AS 780 AS 535 AS 533 AS 530 AS 525 AS 508 AS 540 AF 348 AS 688 AS 525 AS 513 AS 518 AS 355
VF 265 VF 268 VF 265 VF 268 VF 263 VF 265 VF 263 VF 265 VF 263 VF 265 VF 258 VF 268 VF 258 VF 263 VF 255 VF 265 VF 258 VF 260 VF 255 VF 260 VF 258 VF 263 VF 255 VF 260 VF 253
U63% U72% U66% U69% U64% U68% U65% U70% U65% U68% U-- U-- U68% U-- U70% U-- U68% U-- U-- U-- V-Dur Stb V>A U-- Stb V>A U-- Stb V>A U67% Stb V>A Stb V>A U-- U-- Stb V>A U-- Stb V>A

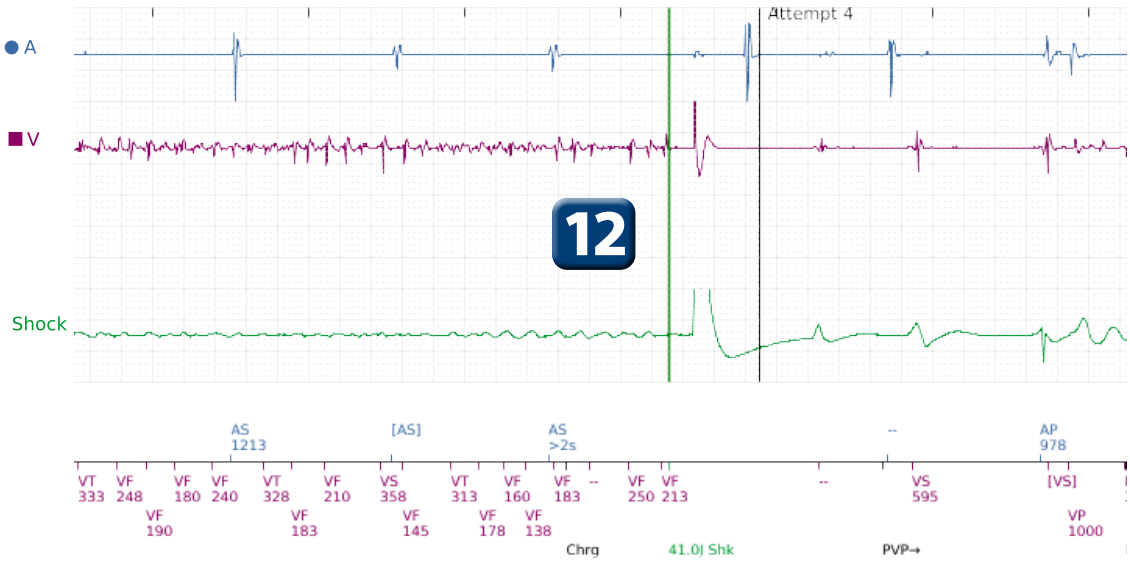

A
V
4
5
6
Shock
AS 673 AS 518 AS 503 AF 278 AS 725 AS 508 AS 920 -- AS 748 AS 905 AS 505 AS 498
VF 255 VF 258 VF 250 VF 255 VF 253 VF 253 VF 250 VF 255 VP 220 VP 220 VP 220 VP 220 VP 220 VP 220 VP 220 VP 220 -- VF 240 VF 255 VF 245 VF 255 VF 245 VF 250 VF 248 VF 253 VF 248
U-- Stb V>A
U-- Stb V>A
U-- Stb V>A
U-- Stb V>A
U-- Stb V>A
U-- Stb V>A
U-- V-Detect Stb V>A
Chrg
A
V
Shock
AS 498 AS 375 AS 623 AS 500 AS 503 AS 495 AS 508 AS 505 AS 500 AS 508 AS 510 AS 510 AS 510
VF 250 VF 250 VF 248 VF 250 VF 250 VF 250 VF 250 VF 250 VF 253 VF 250 VF 250 VF 250 VF 253 VF 253 VF 253 VF 250 VF 253 VF 255 VF 253 VF 255 VF 255 VF 255 VF 253 VF 255 VF 255 VF 255

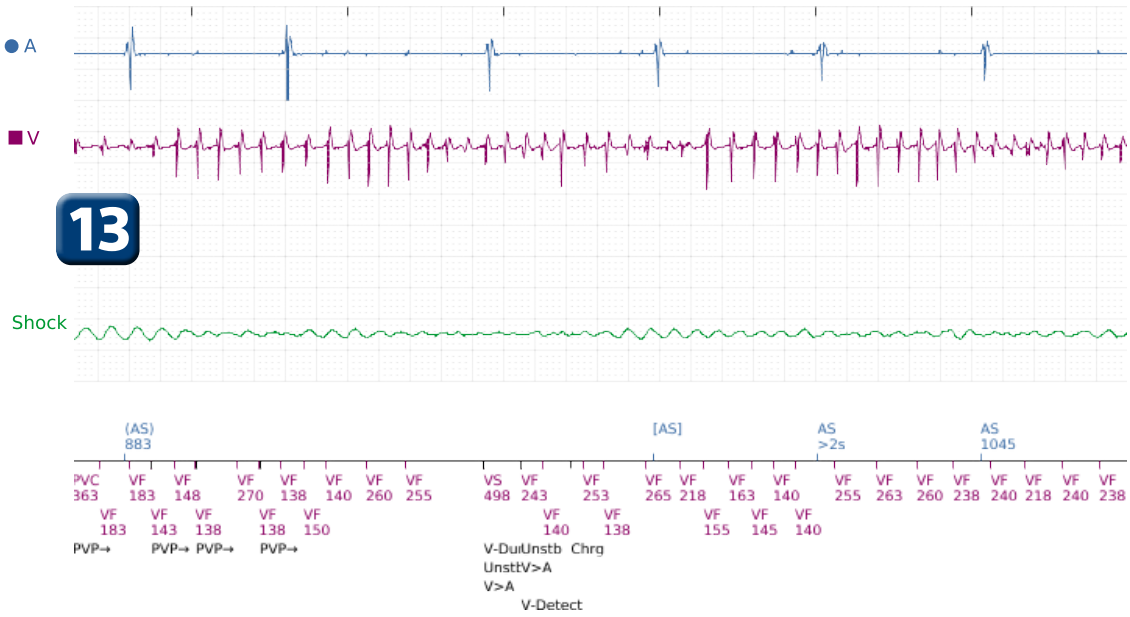

A
V
Shock
Attempt 2
7
8
AS 510
AS 1043
(AS) 1115
[AS]
(AS) 1180
(AS) 628
AS 835
VF 258
VF 255
VF 260
VF 258
VS 838
PVC 700
VS 723
VF 223
VF 233
VF 235
VF 228
VF 230
VF 228
VF 200
VF 168
VF 200
Chrg
41.0J Shk
PVP→

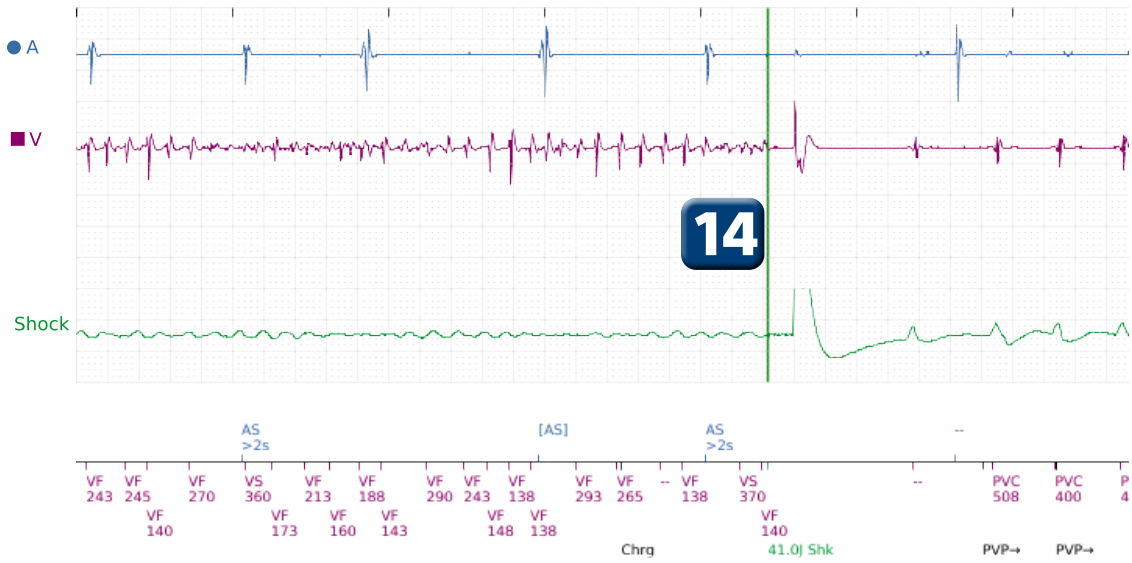

A
V
Shock
9
AS 643
AS 478
AS 450
[AS]
[AS]
AS 1943
AS 1125
AS 505
AS 745
AS 953
VF 205
VS 388
VF 240
VF 203
VT 308
VF 210
VF 225
VF 245
VF 248
VF 228
VF 233
VS 393
VS 383
VF 218
VF 253
VF 225
VF 233
VF 220
VS 528
VF 235
VF 210
VF 250
VF 138
VF 143
VF 140
VF 203
V-Unstb Chrg
Un\V>A
V>A
V-Detect

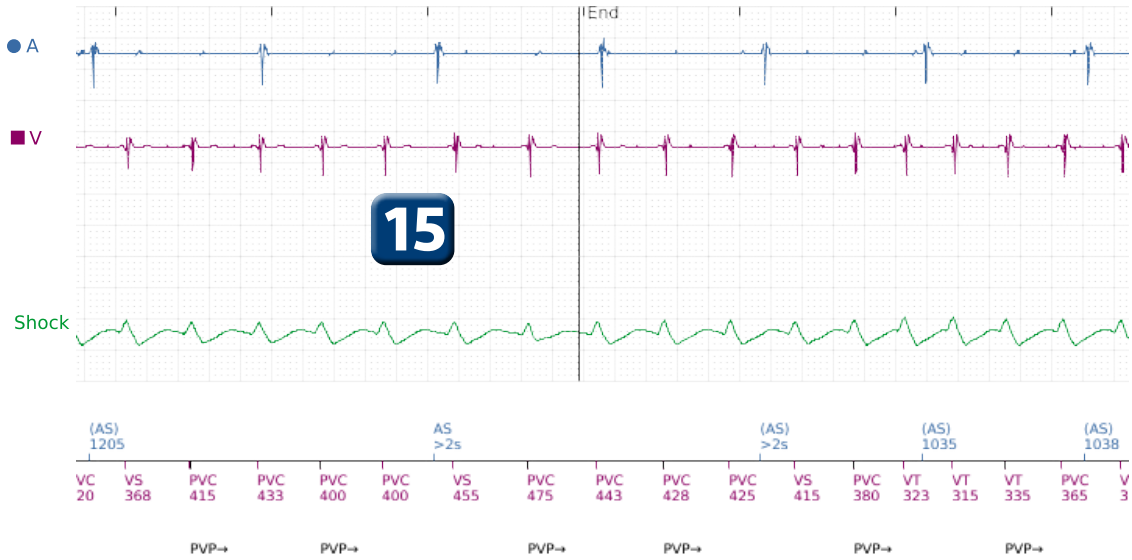
LATITUDE™ Patient Management - Event Detail Report 23 Jan 2023



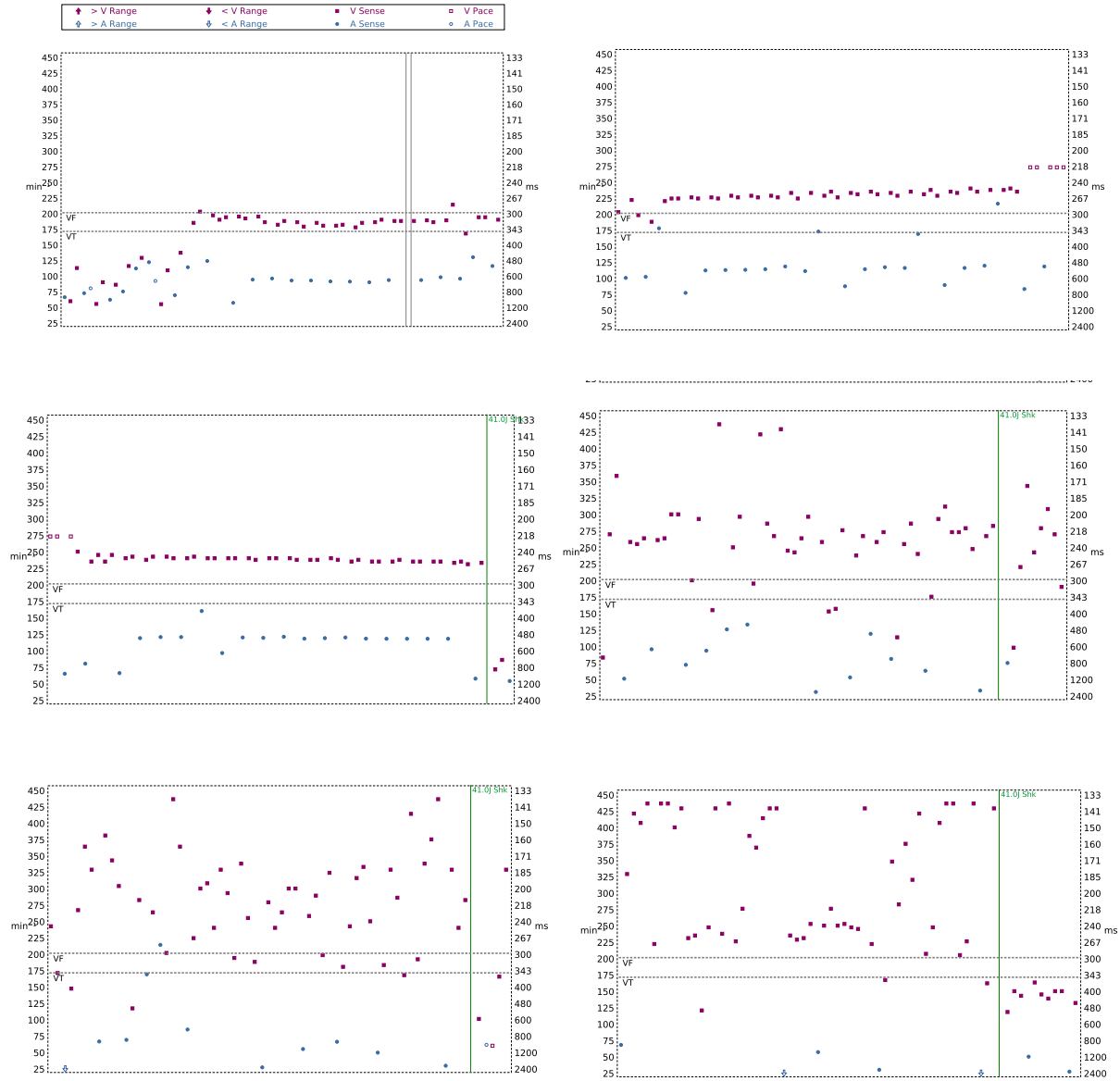

Attempt 4
A
V
12
Shock
AS 1213
[AS]
AS >2s
--
AP 978
VT 333 VF 248 VF 180 VF 240 VT 328 VF 210 VS 358 VT 313 VF 160 VF 183 -- VF 250 VF 213 -- VS 595 [VS]
VF 190 VF 183 VF 145 VF 178 VF 138 VP 1000
Chrg 41.0J Shk PVP→


A
V
13
Shock
(AS) 883
[AS]
AS >2s
AS 1045
PVC 363 VF 183 VF 148 VF 270 VF 138 VF 140 VF 260 VF 255 VS 498 VF 243 VF 253 VF 265 VF 218 VF 163 VF 140 VF 255 VF 263 VF 260 VF 238 VF 240 VF 218 VF 240 VF 238
VF 183 VF 143 VF 138 VF 138 VF 150 VF 140 VF 138 VF 155 VF 145 VF 140
PVP→ PVP→ PVP→ PVP→ V-Dur Unstb Chrg
UnstbV>A
V>A
V-Detect


A
V
14
Shock
AS >2s
[AS]
AS >2s
--
VF 243 VF 245 VF 270 VS 360 VF 213 VF 188 VF 290 VF 243 VF 138 VF 293 VF 265 -- VF 138 VS 370 -- PVC 508 PVC 400
VF 140 VF 173 VF 160 VF 143 VF 148 VF 138 VF 140
Chrg
41.0J Shk
PVP→
PVP→


End
A
V
15
Shock
(AS) 1205
AS >2s
(AS) >2s
(AS) 1035
(AS) 1038
VC 20 VS 368 PVC 415 PVC 433 PVC 400 PVC 400 VS 455 PVC 475 PVC 443 PVC 428 PVC 425 VS 415 PVC 380 VT 323 VT 315 VT 335 PVC 365
PVP→
PVP→
PVP→
PVP→
PVP→
PVP→

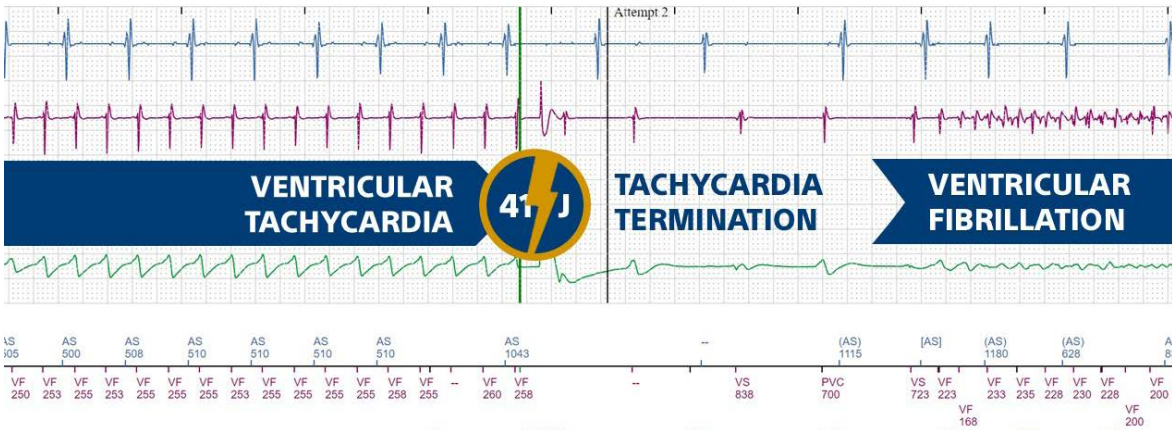
LATITUDE™ Patient Management - Event Detail Report 23 Jan 2023



Points to remember

- the defibrillation threshold does not correspond to a fixed value; several shocks at maximum energy are ineffective in this patient, whereas the fourth shock of the same amplitude averts a dangerous scenario
- a shock is effective if a sufficient critical mass of myocardium is depolarized, establishing an intramyocardial voltage gradient; an electric shock is ineffective if a residual mass of fibrillating myocardium remains, or if there is immediate reinduction in areas where the induced gradient is insufficient; these tracings show that the shock terminates a disorganized ventricular arrhythmia with almost immediate reinitiation
- when the first shock is ineffective, a vicious cycle sets in; prolonged duration of VF worsens hemodynamics, ischemia and myocardial stretch, reducing the probability of a successful subsequent shock
- a shock most often terminates episodes of ventricular arrhythmia and is the basic treatment of the defibrillator; however, the shock can sometimes be pro-arrhythmogenic and, as in this patient, transform an organized VT into a potentially lethal VF (stable VT before the first shock and VF afterwards)
- the effect of a shock varies according to the energy delivered; for low energy, a shock in a vulnerable period can induce arrhythmia; the upper limit of vulnerability corresponds to the lowest energy, applied in a vulnerable ventricular period, which does not induce ventricular fibrillation; this value is correlated with the defibrillation threshold; the probability of termination then increases following an exponential probability curve as a function of the amplitude of the shock delivered (synchronized to the R wave); above a certain value, the risk of re-inducing an arrhythmia also increases, limiting the chances of successful therapy; a shock with too high an amplitude can damage myocardial tissue

- in this patient, the first shock degraded a monomorphic, organized arrhythmia into a polymorphic, chaotic one, suggesting the existence of a high defibrillation threshold; the shock failed to capture a sufficient quantity of ventricular myocardium, and instead created sufficient pro-arrhythmogenic myocardial heterogeneity to generate multiple reentry circuits; it is therefore not surprising that subsequent delivery of the same amount of energy did not terminate the episode of VF induced by the first shock, and that several shocks were required (immediate reentry); to defibrillate, a shock must significantly modify the trans-membrane potential to interrupt the waves of fibrillation; however, if new fronts are created, immediate reentry of VF may be observed
- in this patient, safety seemed compromised with few reprogramming options available; a coil positioned in the coronary sinus was added; in fact, a shock delivered between two electrodes in contact with or in the immediate vicinity of the cardiac mass is more likely to be effective by extending the induced electric field over a larger volume



The tracing shows how the shock delivered during a monomorphic tachycardia (VT) interrupts the tachycardia with immediate reinduction of a polymorphic, disorganized, low-voltage arrhythmia (VF).

5 VF, device shock with AF induction

Patient

- 72-year-old male with ischemic cardiomyopathy; implanted with an Incepta dual-chamber defibrillator

Summary

- episode classified in the VF zone
- electric shock of 41 Joules

EGM layout

1. rrapid ventricular arrhythmia with atrioventricular dissociation
2. ventricular undersensing but 6/10 criterion remains verified
3. ATP Quick Convert
4. ineffective ATP and capacitor charging
5. end of charge with shock delivery
6. termination of ventricular arrhythmia
7. atrial cycle sensed in the refractory period; atrial pacing in the vulnerable atrial period
8. induction of AF

LATITUDE™ Patient Management - Event Detail Report	Report Created: 25 Jan 2023

Boston Scientific

Date of Birth:
Device: **AUTOGEN EL ICD D176**
Clinic:
Search Tags:
Tachy Mode: **Monitor + Therapy**

Latest Device Transmission: **24 Jan 2023 00:50 CET**
Last Office Interrogation: **01 Dec 2022**
Implant Date:
Patient Group:

V-106: 14 Mar 2019 03:22, VF, A Rate: 42 min^{-1}, V Rate: 240 min^{-1}

Detail

VF Event Onset

Avg A Rate	42 min^{-1}
Avg V Rate	240 min^{-1}
Detection	Rhythm ID
Template	13 Mar 2019 19:41
RhythmMatch™ Threshold	94 %

At V-Detect

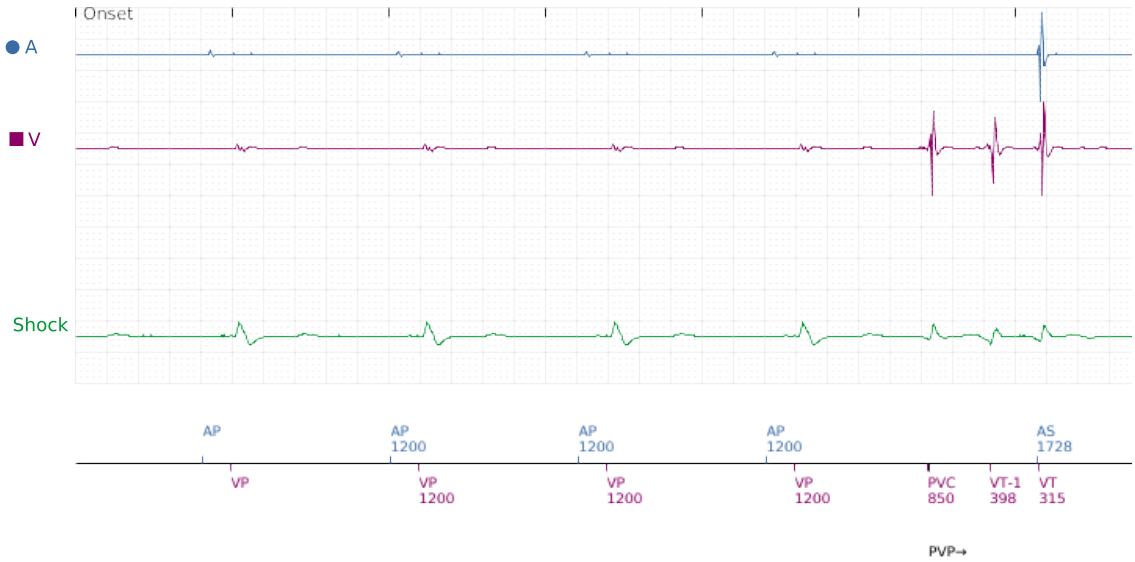
Avg A Rate	47 min^{-1}
Avg V Rate	279 min^{-1}
Rate Zone	VF
Stability	(69 ms, Off)
V>A Rate	(True, Off)
AFib	(False, Off)
RhythmID Correlated	False
RhythmMatch™	30 %
SRD Met	(False, Off)
ATP Timeout	False

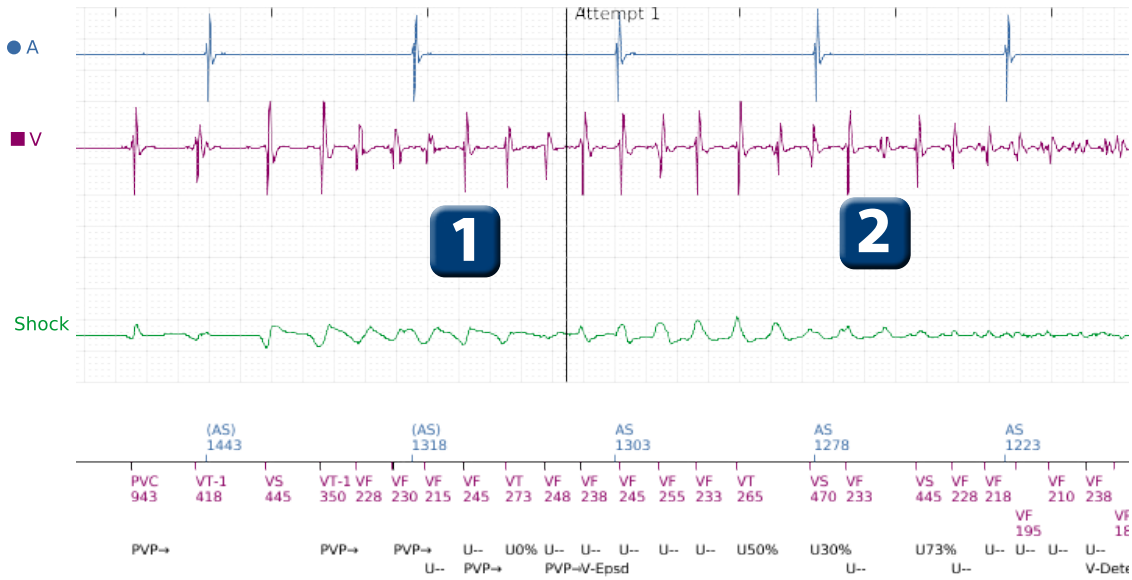
Attempt 1, 41 J V Shock

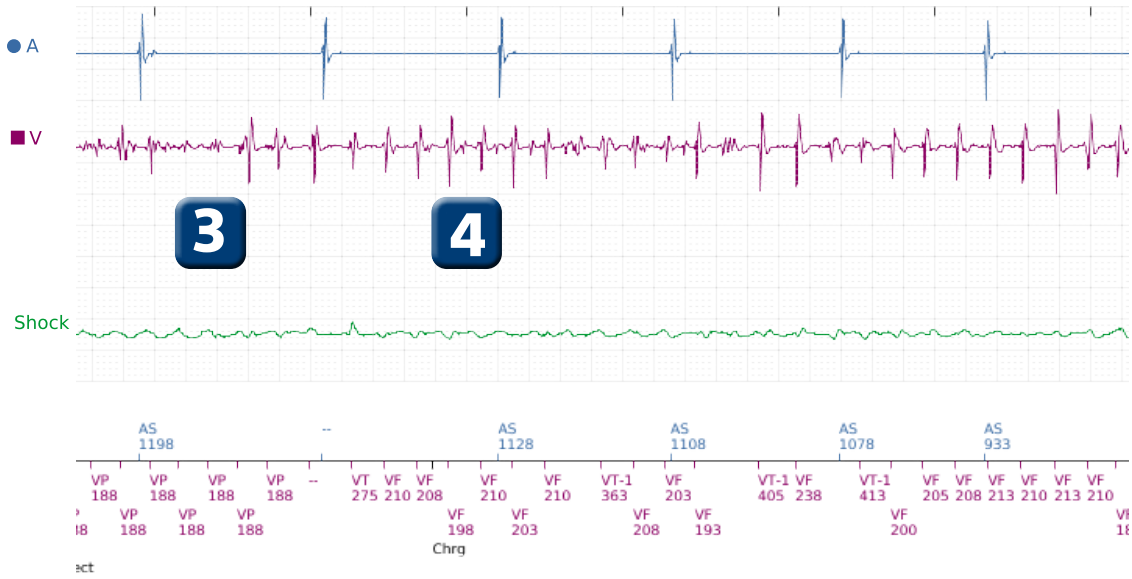
Elapsed Time	00:00:03
VF ATP delivered prior to shock	
Shock Information	
Charge Time	9.7 s
Lead Impedance	60 Ω
Lead Polarity	Initial

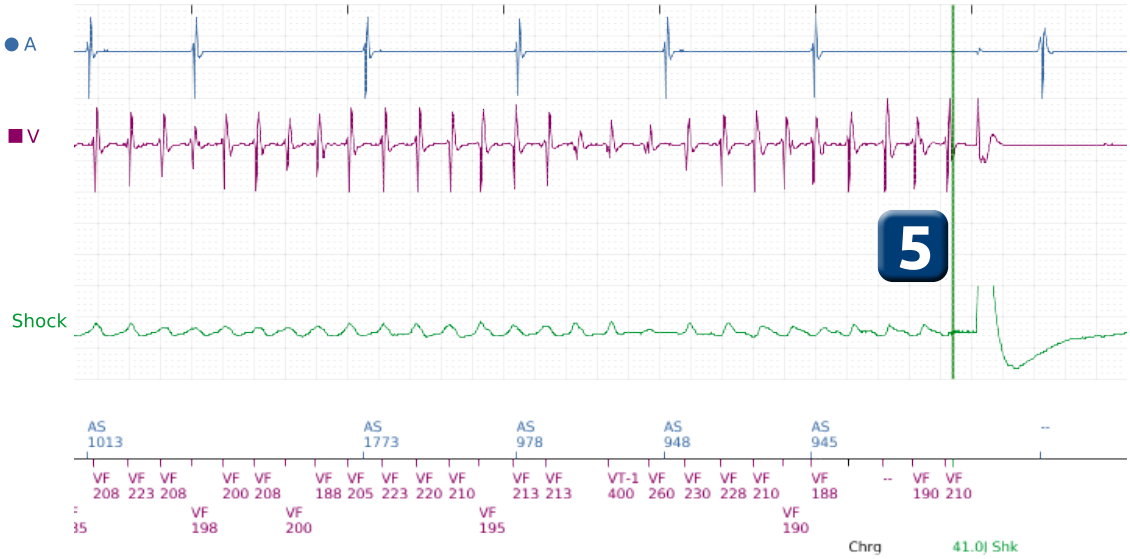
Event Ended 00:00:48

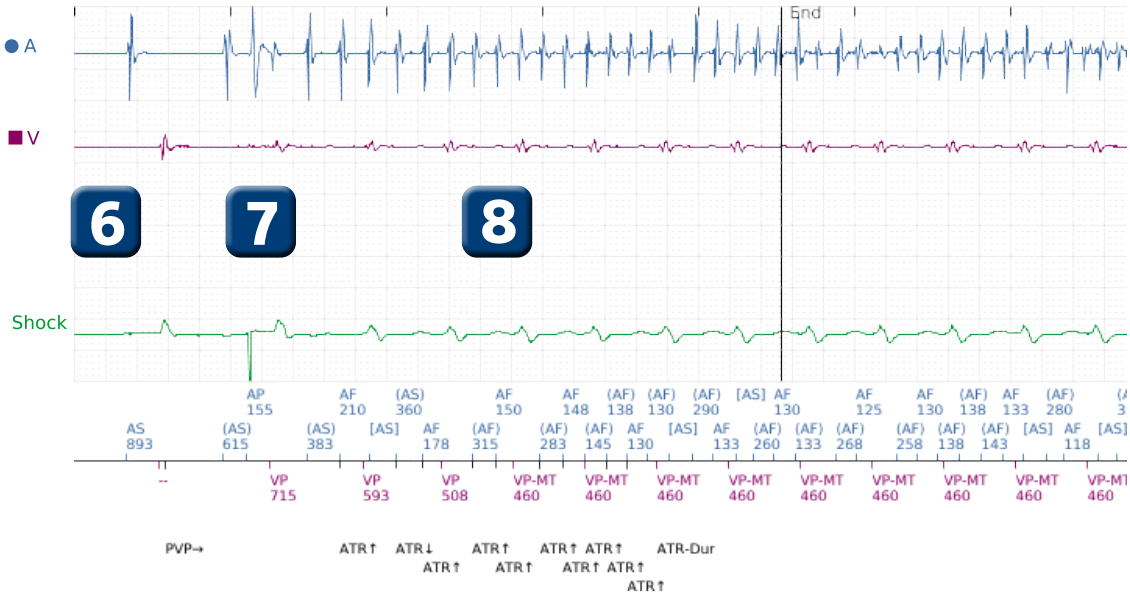
EGM displayed at 25mm per second

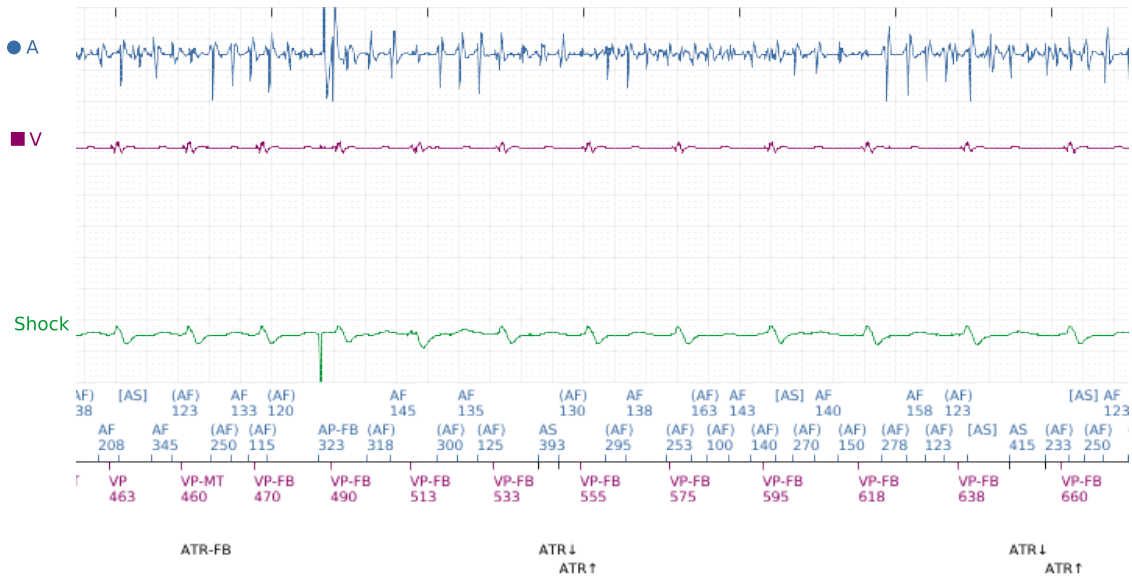


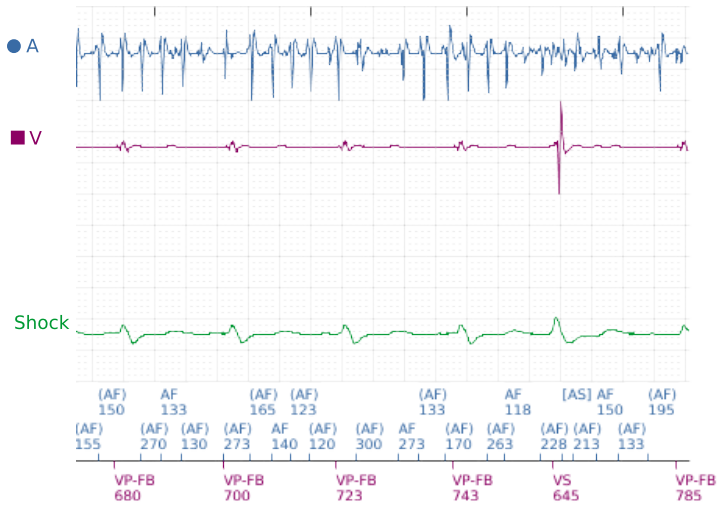

Attempt 1
A
V
Shock
1
2
(AS) 1443
(AS) 1318
AS 1303
AS 1278
AS 1223
PVC 943
VT-1 418
VS 445
VT-1 350
VF 228
VF 230
VF 215
VF 245
VT 273
VF 248
VF 238
VF 245
VF 255
VF 233
VT 265
VS 470
VF 233
VS 445
VF 228
VF 218
VF 195
VF 210
VF 238
PVP→
PVP→
PVP→
U--
U0%
U50%
U30%
U73%
V-Epsd
V-Dete

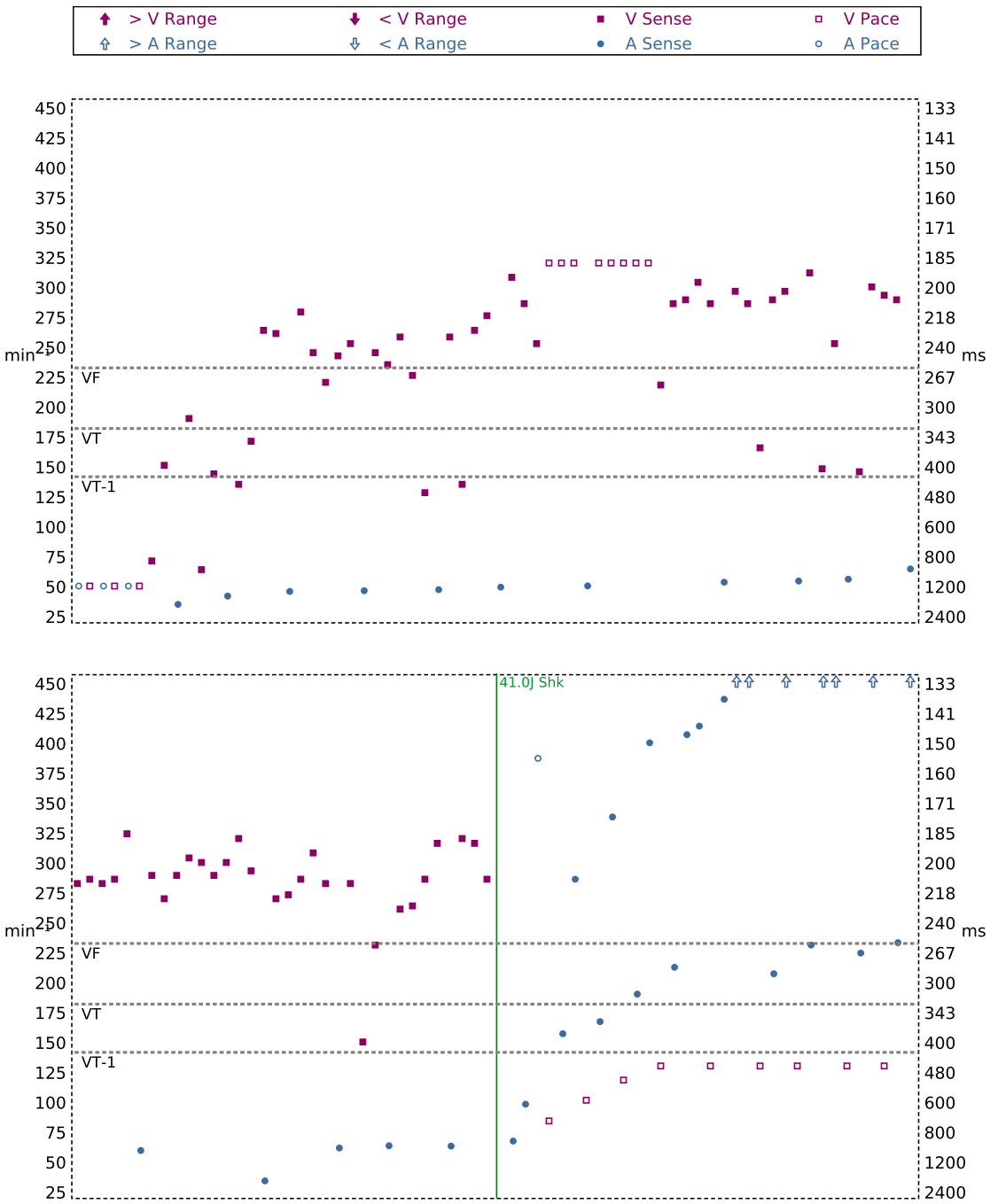

A
V
Shock
3
4
AS 1198
AS 1128
AS 1108
AS 1078
AS 933
VP 188
VT 275
VF 210
VF 208
VF 198
VF 203
VT-1 363
VF 203
VF 208
VF 193
VT-1 405
VF 238
VT-1 413
VF 200
VF 205
VF 208
VF 213
VF 210
VF 213
VF 210
Chrg


A
V
5
Shock
AS 1013
AS 1773
AS 978
AS 948
AS 945
VF 208 VF 223 VF 208
VF 200 VF 208
VF 188 VF 205 VF 223 VF 220 VF 210
VF 213 VF 213
VT-1 400 VF 260 VF 230 VF 228 VF 210
VF 188
VF 190 VF 210
VF 198
VF 200
VF 195
VF 190
Chrg
41.0J Shk


End
A
V
6
7
8
Shock
AS 893
(AS) 615
(AS) 383
[AS]
AP 155
AF 210
(AS) 360
AF 178
(AF) 315
AF 150
(AF) 283
AF 148
(AF) 145
(AF) 138
AF 130
(AF) 130
[AS]
(AF) 290
AF 133
[AS]
AF 130
(AF) 260
(AF) 133
(AF) 268
AF 125
(AF) 258
AF 130
(AF) 138
(AF) 143
AF 133
(AF) 138
[AS]
(AF) 280
AF 118
[AS]
VP 715
VP 593
VP 508
VP-MT 460
PVP→
ATR↑
ATR↓
ATR-Dur

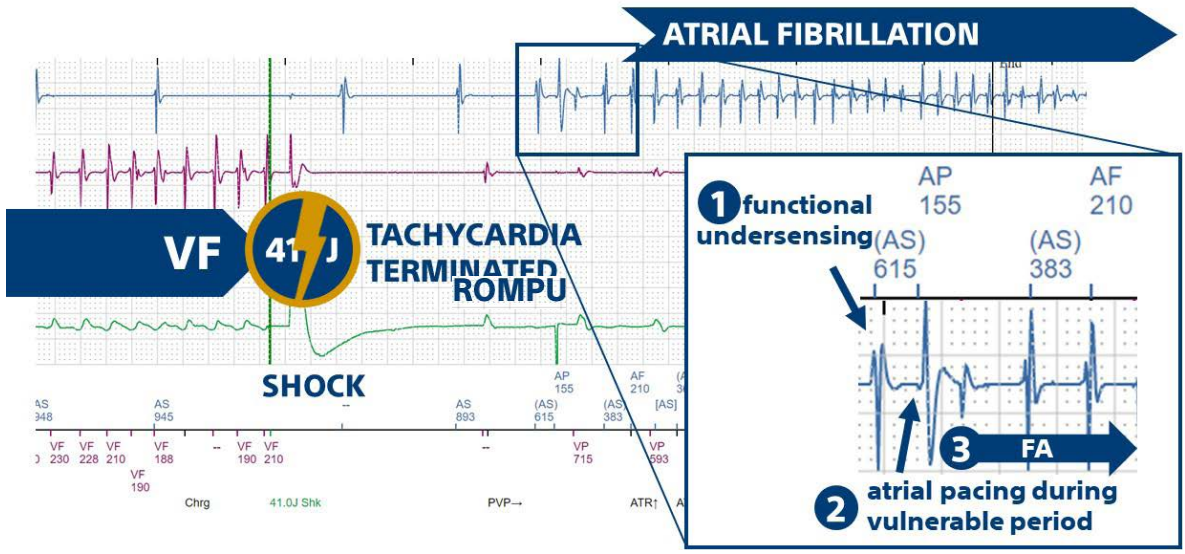

A
V
Shock
VP 463
VP-MT 460
VP-FB 470
VP-FB 490
VP-FB 513
VP-FB 533
VP-FB 555
VP-FB 575
VP-FB 595
VP-FB 618
VP-FB 638
VP-FB 660
ATR-FB
ATR↓
ATR↑
ATR↓
ATR↑


A
V
Shock
VP-FB 680
VP-FB 700
VP-FB 723
VP-FB 743
VS 645
VP-FB 785


> V Range
< V Range
V Sense
V Pace
> A Range
< A Range
A Sense
A Pace
min
ms
VF
VT
VT-1
41.0J Shk

Points to remember

- shocks delivered for VT or VF are synchronized with ventricular sensing, regardless of the phase of the atrial cycles
- although the exact incidence of this pro-arrhythmic effect is not well known, an electric shock delivered by a defibrillator in the setting of a ventricular arrhythmia can induce an AF episode when it occurs during the vulnerable atrial period
- various studies have shown that the risk of AF induction seems higher for low-energy shocks, particularly when one of the coils is located in the right atrium (double-coil shock)
- induced AF episodes are generally relatively short, although more sustained episodes may occur in patients with an abnormal atrial substrate



The tracing shows how the shock delivered during VF terminates ventricular arrhythmia, with immediate onset of AF (probable combined effect of the pro-arrhythmogenic effect of the shock and atrial pacing in a vulnerable period).

6 ATP burst in the VF zone

Patient

- 72-year-old male with a dilated cardiomyopathy; implanted with an Autogen dual-chamber defibrillator

Summary

- episode classified in the VF zone
- ATP in the VF zone
- 2 shocks of 41 Joules

EGM layout

1. sinus rhythm
2. regular, monomorphic VT detected in the VF zone
3. initial detection satisfied for the VF zone (8 cycles out of 10 in FV zone); start of initial VF zone duration (1 second)
4. detection of a VF episode (V-Detect); ventricular rate measured over the 4 cycles preceding the V-Detect marker is below 250 beats/minute (229 bpm)
5. ATP Quick Convert: burst of 8 stimuli at a fixed rate (identical coupling between the last sensed cycle and the first paced cycle, then between the different paced cycles).
6. the first atrial and ventricular cycles following ATP are not counted (--)
7. the device analyzes the effectiveness of the ATP sequence: the first 2 cycles are considered slow (VS); the 2 cycles/3 slow criterion is therefore met and capacitor charging is diverted (dvrt)

8 end of episode (V-EpsdEnd marker)

9 recurrence of the same VT

10 ATP Quick Convert (burst of 8 impulses at fixed frequency)

11 the first atrial and ventricular cycles following ATP are not counted (--)

12 the device analyzes the effectiveness of the ATP sequence: the first 2 cycles are considered fast (VF-VT); the 2 cycles / 3 fast criterion is therefore met and capacitor charging begins (Chrg)

13 end of charge, 500 ms diversion window; shock on the second fast cycle

14 effective shock and return of sinus of rhythm

15 recurrence of an identical VT before the end-of-episode criterion (30 seconds after the shock has been delivered)

16 end of duration; even if the rate is below 250 bpm, the ATP sequence in the VF zone cannot be delivered (only 1 sequence for a single episode, as the current episode has not ended).

17 capacitor charging

18 shock and arrhythmia termination

LATITUDE™ Patient Management - Event Detail Report	Report Created: 23 Jan 2023

Boston Scientific

Date of Birth:
Device: **AUTOGEN EL ICD D176**
Clinic:
Search Tags:
Tachy Mode: **Monitor + Therapy**

Latest Device Transmission: **23 Jan 2023 02:41 CET**
Last Office Interrogation: **21 Oct 2022**
Implant Date:
Patient Group:

V-54: 12 Nov 2018 16:40, VF, A Rate: 98 min^{-1}, V Rate: 235 min^{-1}

Detail

VF Event Onset

Avg A Rate	98 min^{-1}
Avg V Rate	235 min^{-1}
Detection	Rhythm ID
Template	12 Nov 2018 14:47
RhythmMatch™ Threshold	94 %

At V-Detect

Avg A Rate	77 min^{-1}
Avg V Rate	229 min^{-1}
Rate Zone	VF
Stability	(5 ms, Off)
V>A Rate	(True, Off)
AFib	(False, Off)
RhythmID Correlated	False
RhythmMatch™	Too Fast
SRD Met	(False, Off)
ATP Timeout	False

Attempt 1, 41 J V Shock

Elapsed Time	00:00:03
VF ATP delivered prior to shock	
Shock Information	
Charge Time	7.3 s
Lead Impedance	61 Ω
Lead Polarity	Initial

At V-Detect

Avg A Rate	108 min^{-1}
Avg V Rate	231 min^{-1}
Rate Zone	VF
Stability	(8 ms, Off)
V>A Rate	(True, Off)
AFib	(False, Off)
SRD Met	(False, Off)
ATP Timeout	False

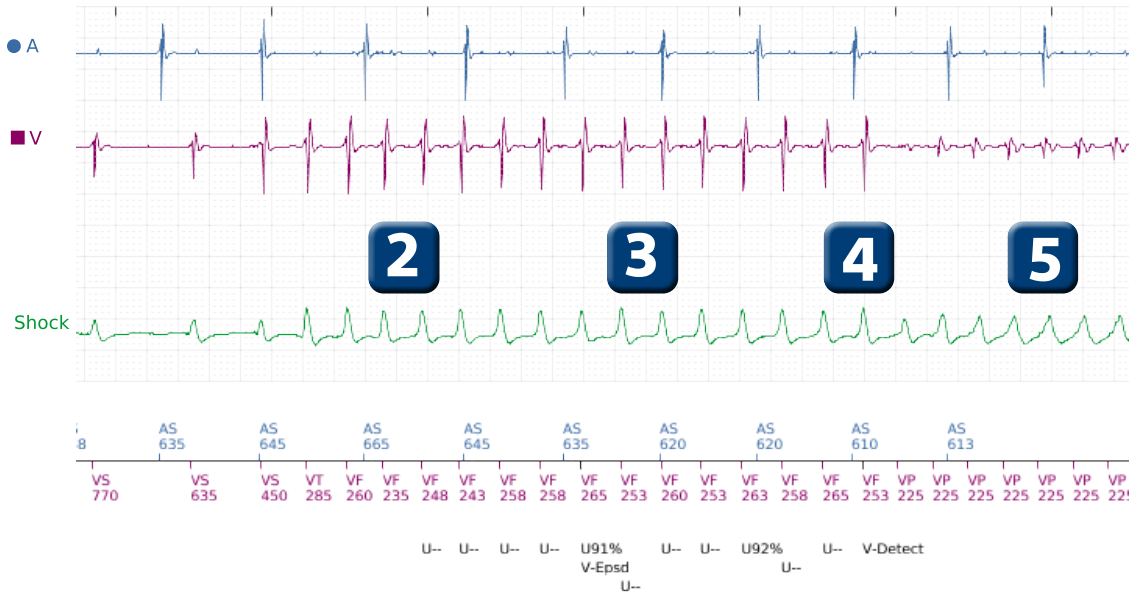
Attempt 2, 41 J V Shock

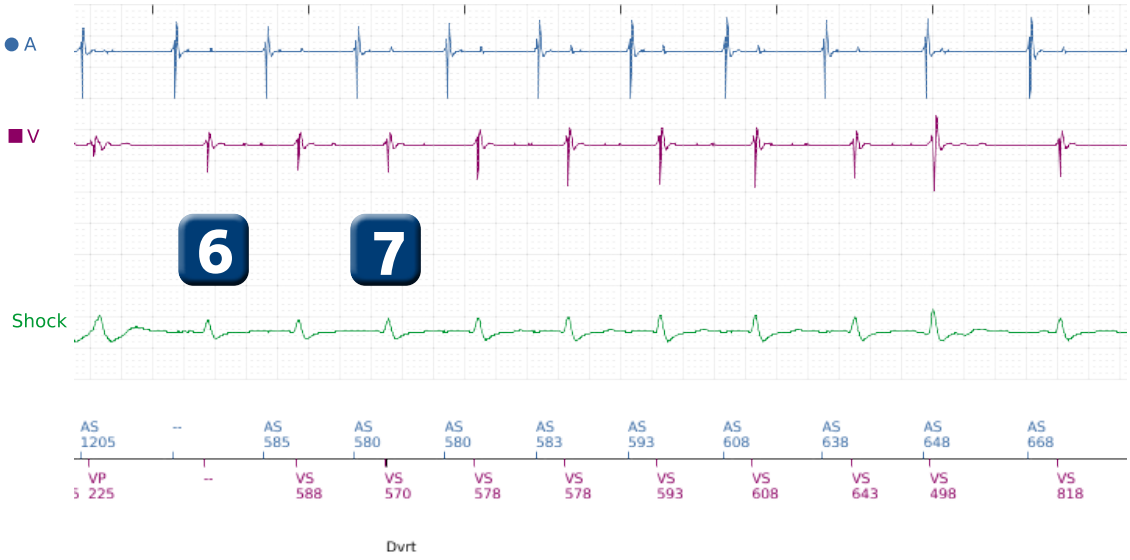
Elapsed Time	00:00:36
Shock Information	
Charge Time	7.0 s
Lead Impedance	62 Ω
Lead Polarity	Initial

Event Ended 00:01:14

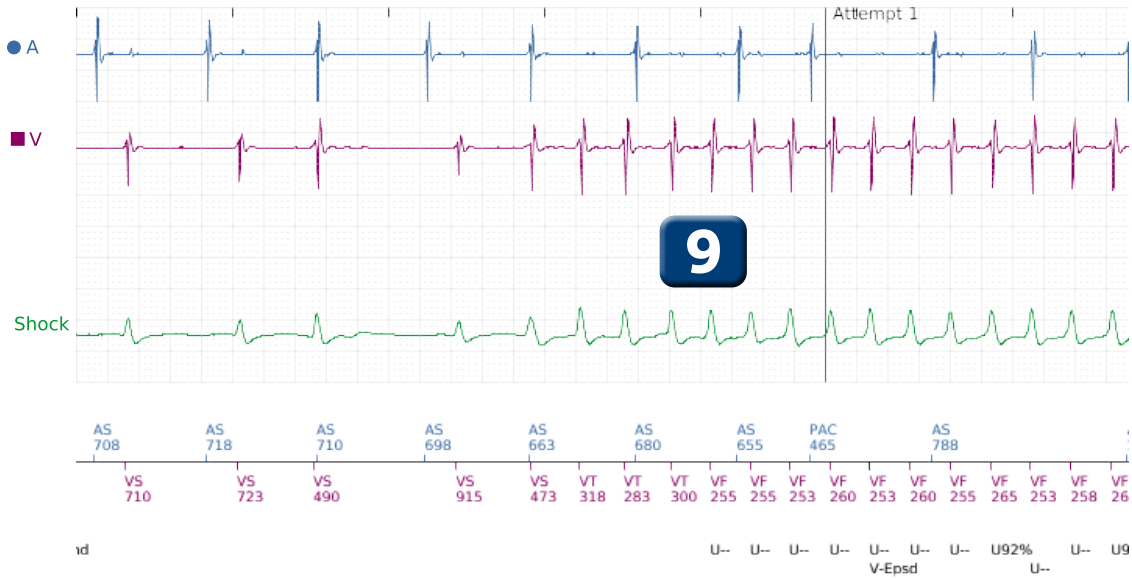
EGM displayed at 25mm per second

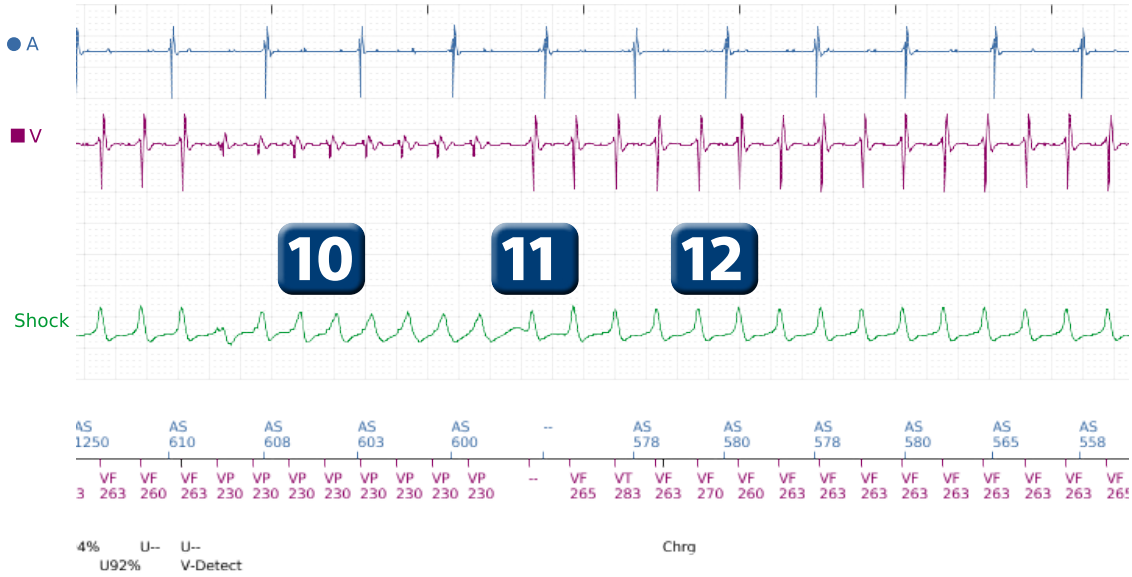

Onset
A
V
Shock
1
AS AS AS AS AS AS AS AS AS AS AS
630 638 628 638 628 633 628 645 633 64
VS VS VS VS VS VS VS VS VS VS
518 753 525 743 508 748 518 755 515

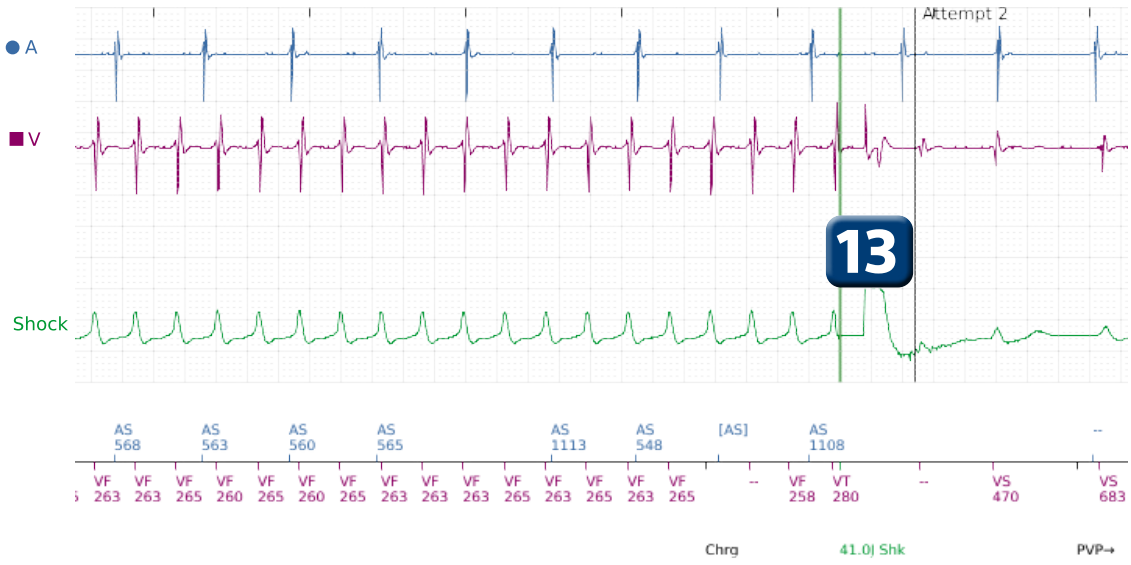

A
V
Shock
2
3
4
5
AS AS AS AS AS AS AS AS AS AS
635 645 665 645 635 620 620 610 613
VS VS VS VT VF VF VF VF VF VF VF VF VF VF VF VF VF VP VP VP VP VP VP
770 635 450 285 260 235 248 243 258 258 265 253 260 253 263 258 265 253 225 225 225 225 225 225
U-- U-- U-- U-- U91% V-Epsd U-- U-- U-- U92% U-- U-- V-Detect

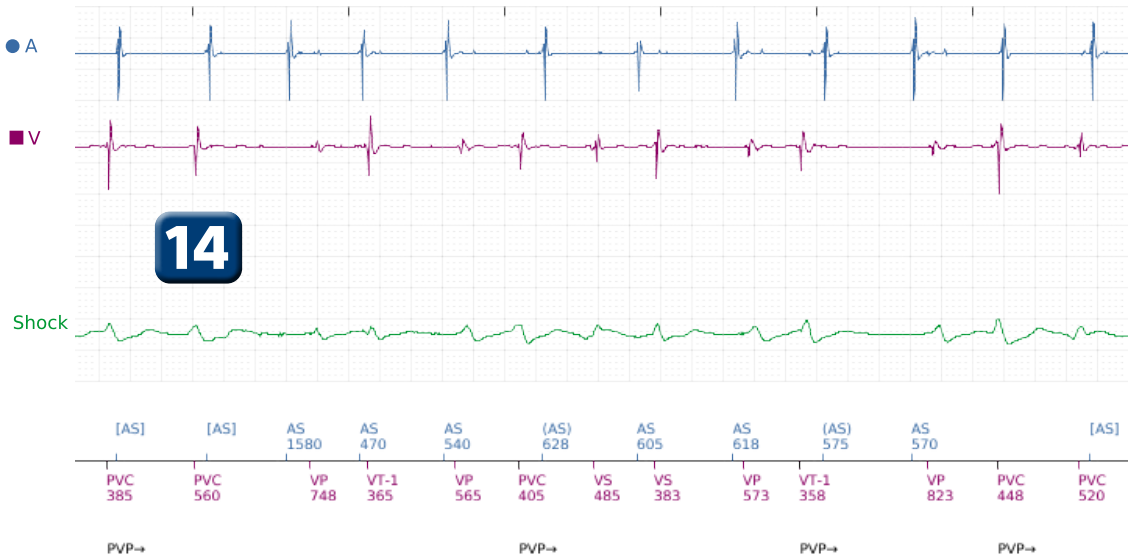

A
V
6
7
Shock
AS 1205
--
AS 585
AS 580
AS 580
AS 583
AS 593
AS 608
AS 638
AS 648
AS 668
VP 225
--
VS 588
VS 570
VS 578
VS 578
VS 593
VS 608
VS 643
VS 498
VS 818
Dvrt


A
V
8
Shock
AS 643
AS 670
AP 1000
AP 1000
AS 715
AS 693
AS 683
AS 693
AS 698
VS 643
VS 665
VS 488
VS 615
VS 910
VS 718
VS 690
VS 683
VS 688
VS 700
V-EpsdEr

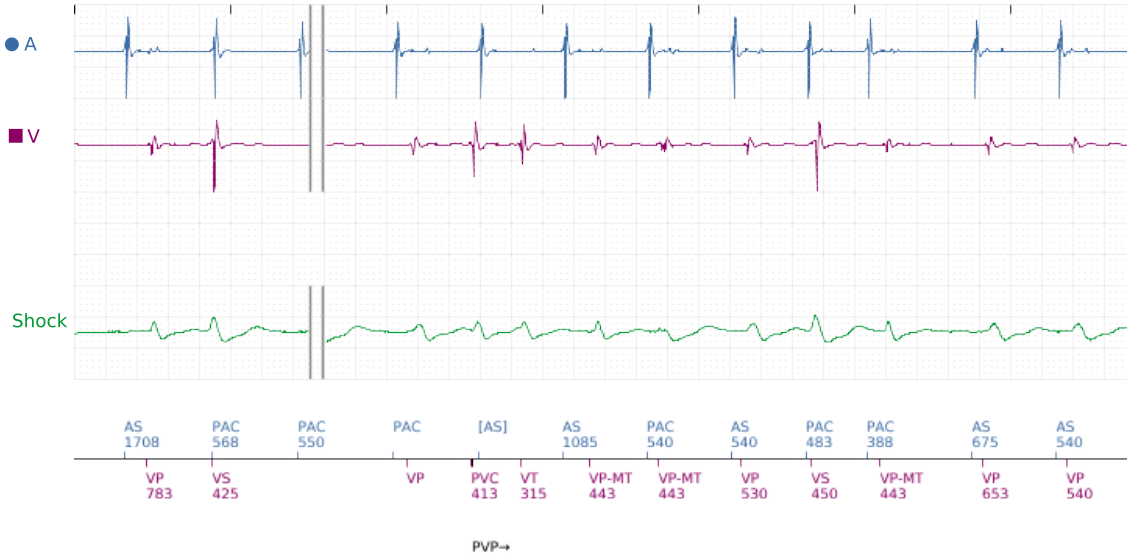

A
V
Shock
Attempt 1
9
AS 708
AS 718
AS 710
AS 698
AS 663
AS 680
AS 655
PAC 465
AS 788
VS 710
VS 723
VS 490
VS 915
VS 473
VT 318
VT 283
VT 300
VF 255
VF 255
VF 253
VF 260
VF 253
VF 260
VF 255
VF 265
VF 253
VF 258
U-- U-- U-- U-- U-- U-- U-- U92% U-- U--
V-Epsd
U--

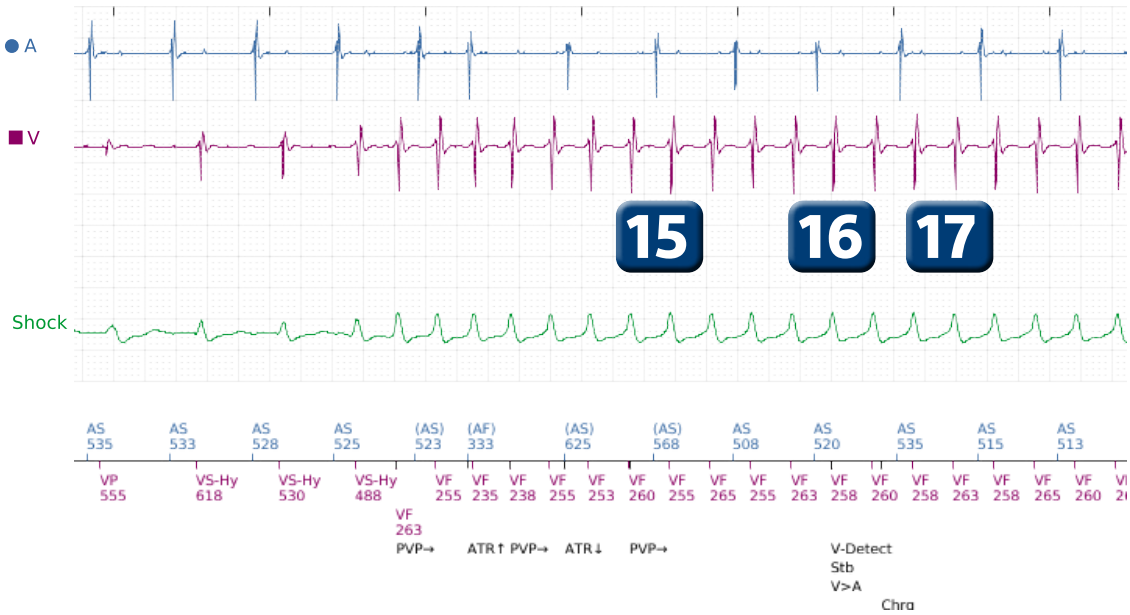

A
V
Shock
10
11
12
AS 1250
AS 610
AS 608
AS 603
AS 600
AS 578
AS 580
AS 578
AS 580
AS 565
AS 558
VF 263
VF 260
VF 263
VP 230
VP 230
VP 230
VP 230
VP 230
VP 230
VP 230
VP 230
VF 265
VT 283
VF 263
VF 270
VF 260
VF 263
VF 263
VF 263
VF 263
VF 263
VF 263
VF 263
4% U-- U--
U92% V-Detect
Chrg

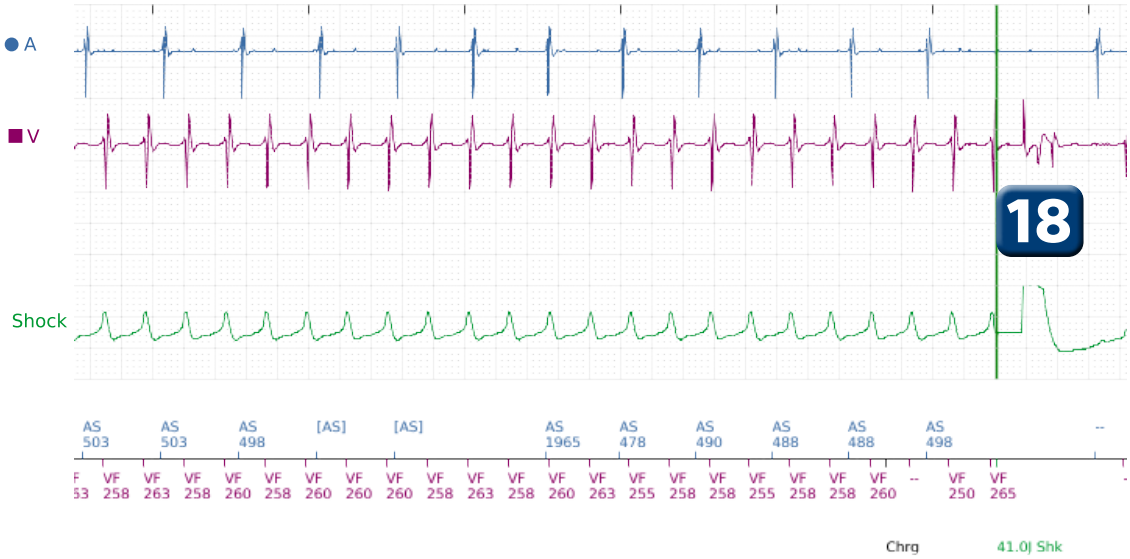

A
V
Shock
Attempt 2
13
AS 568
AS 563
AS 560
AS 565
AS 1113
AS 548
[AS]
AS 1108
VF 263 VF 263 VF 265 VF 260 VF 265 VF 260 VF 265 VF 263 VF 263 VF 263 VF 265 VF 263 VF 265 VF 263 VF 265
VF 258 VT 280
VS 470
VS 683
Chrg
41.0J Shk
PVP→

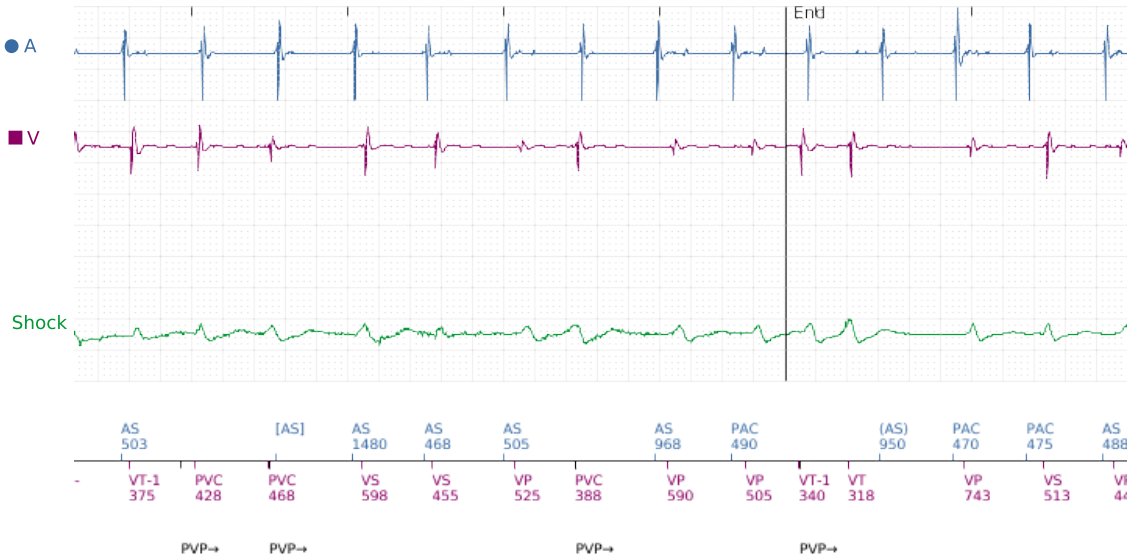

A
V
Shock
14
[AS] [AS] AS 1580 AS 470 AS 540 (AS) 628 AS 605 AS 618 (AS) 575 AS 570 [AS]
PVC 385 PVC 560 VP 748 VT-1 365 VP 565 PVC 405 VS 485 VS 383 VP 573 VT-1 358 VP 823 PVC 448 PVC 520
PVP→
PVP→
PVP→
PVP→

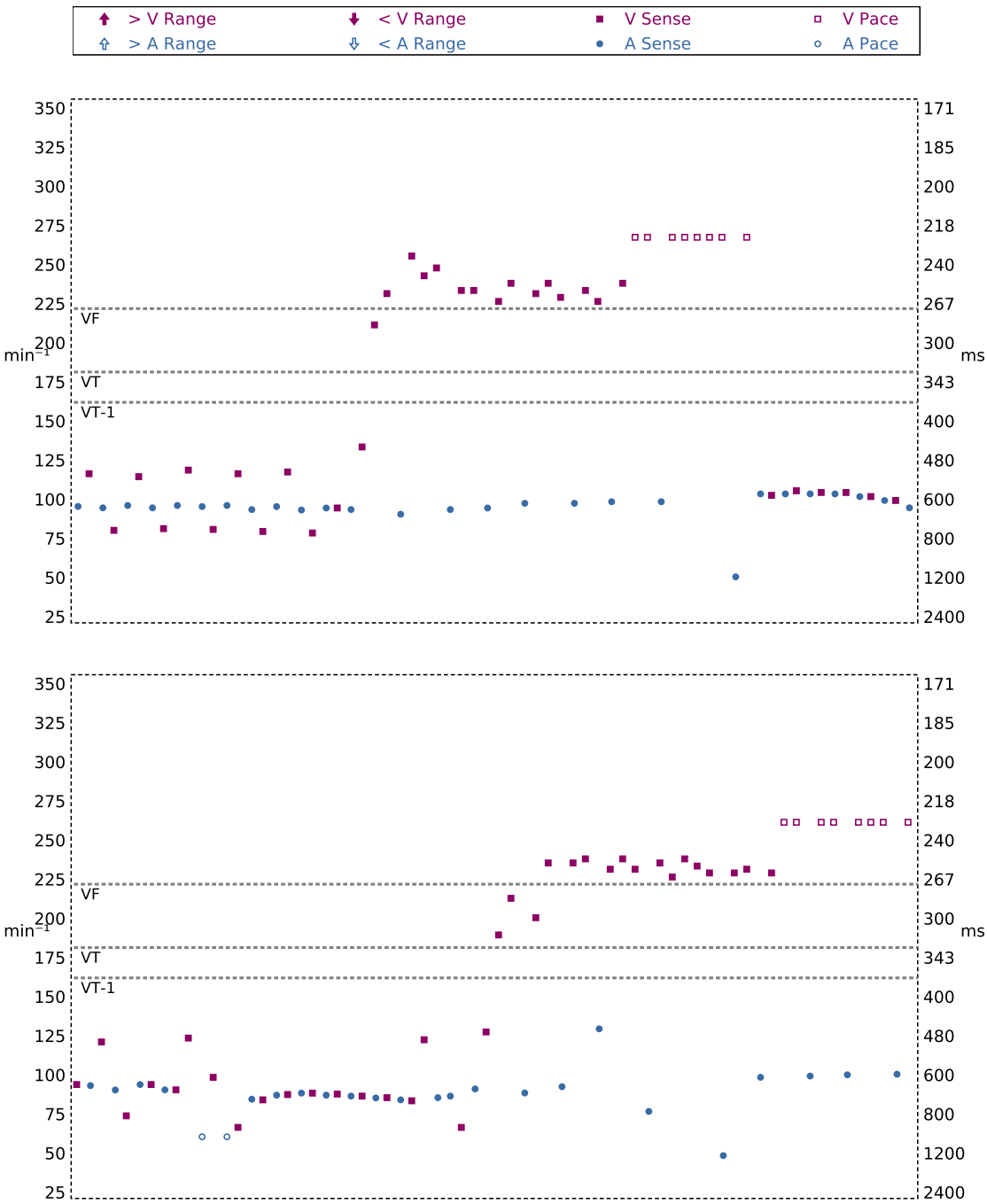
LATITUDE™ Patient Management - Event Detail Report **23 Jan 2023**






A
V
18
Shock
AS 503 AS 503 AS 498 [AS] [AS] AS 1965 AS 478 AS 490 AS 488 AS 488 AS 498
VF 258 VF 263 VF 258 VF 260 VF 258 VF 260 VF 260 VF 260 VF 258 VF 263 VF 258 VF 260 VF 263 VF 255 VF 258 VF 258 VF 255 VF 258 VF 258 VF 260 VF 250 VF 265
Chrg
41.0J Shk


End
A
V
Shock
AS 503 [AS] AS 1480 AS 468 AS 505 AS 968 PAC 490 (AS) 950 PAC 470 PAC 475 AS 488
VT-1 375 PVC 428 PVC 468 VS 598 VS 455 VP 525 PVC 388 VP 590 VP 505 VT-1 340 VT 318 VP 743 VS 513
PVP→ PVP→ PVP→ PVP→


> V Range
< V Range
V Sense
V Pace
> A Range
< A Range
A Sense
A Pace
min⁻¹
ms
VF
VT
VT-1
350
325
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225
200
175
150
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25
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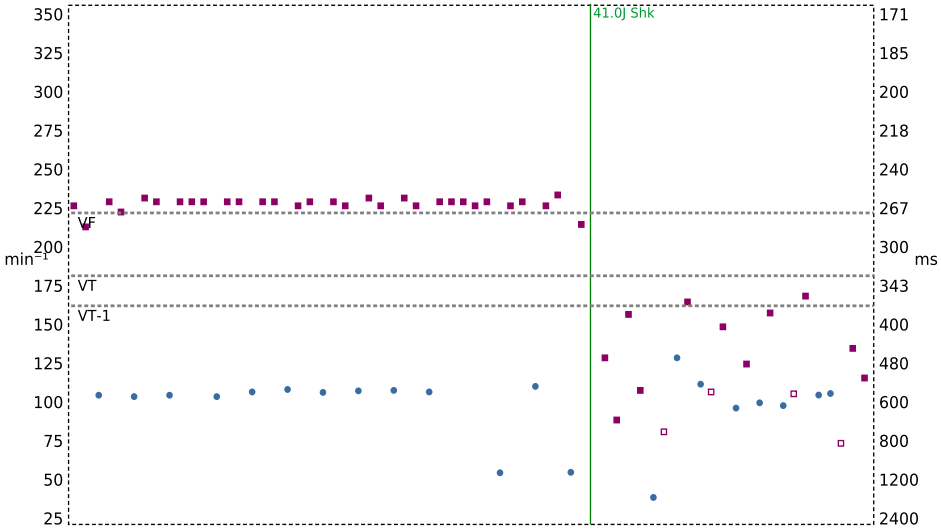
41.0J Shk
VF
VT
VT-1
min⁻¹
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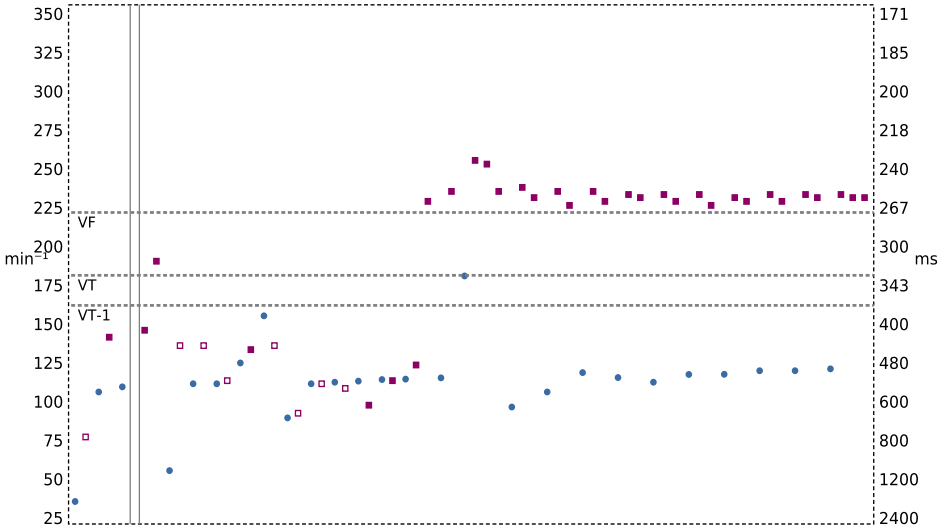
VF
VT
VT-1
min⁻¹
ms
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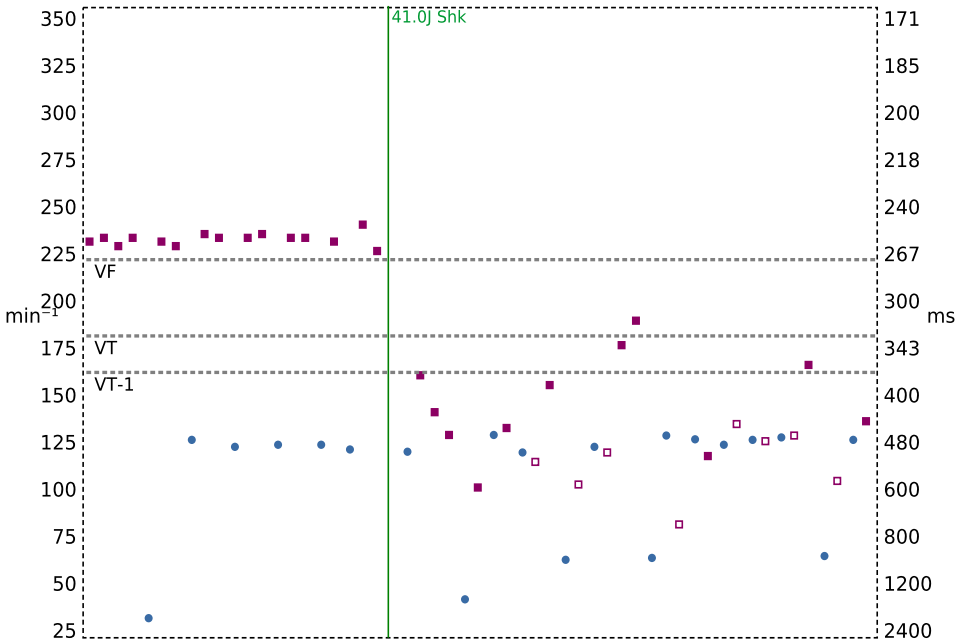
41.0J Shk
VF
VT
VT-1
min⁻¹
ms
350
325
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225
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175
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125
100
75
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25
171
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267
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343
400
480
600
800
1200
2400

Points to remember

- although it is clear that delivering a shock during an episode of ventricular fibrillation is the only therapy likely to restore a viable rhythm for the patient, optimal programming must ensure that the number of shocks delivered (inappropriate or appropriate but avoidable) by the device is minimized as much as possible
- a shock is painful when delivered to a conscious patient, and significantly increases energy consumption; the succession of several shocks to the same patient is therefore associated with a risk of premature battery depletion and a marked deterioration in quality of life (numerous cases of depression or anxiety induced by a series of shocks have been described)
- an endocardial shock is accompanied by microscopic myocardial lesions, an increase in cardiac humoral markers (troponin, CPK, myoglobin) and macroscopic lesions that are more significant with higher energy delivery (momentary drop in left ventricular ejection fraction and cardiac output, particularly in patients with already impaired contractility)
- a significant correlation has been found between mortality and the number of shocks delivered (notion of paradoxical shock effect); in the Sudden Cardiac Death in Heart Failure Trial (SCD-HeFT) and MADIT II studies and in a meta-analysis of 4 large studies, patients who received one or more appropriate or inappropriate shocks had significantly increased mortality; the main cause of death after shocks was a worsening heart failure; in contrast the meta-analysis found that delivering one or more sequences of anti-tachycardia pacing did not alter prognosis
- whether shocks are really an independent predictor of mortality, or simply a marker of the severity of the patient's clinical condition, remains controversial; however, it is now recommended (class I) that anti-tachycardia pacing should be used as a first-line attempt at termination, up to relatively high heart rates (230 beats/minute); electric shocks are only proposed as a second-line treatment after failure of anti-tachycardia

pacing, unless anti-tachycardia pacing has proved ineffective or deleterious (acceleration of arrhythmia); in fact, delivering an anti-tachycardia pacing sequence in a VF zone is often effective, painless, reduces battery consumption, improves quality of life and does not alter prognosis

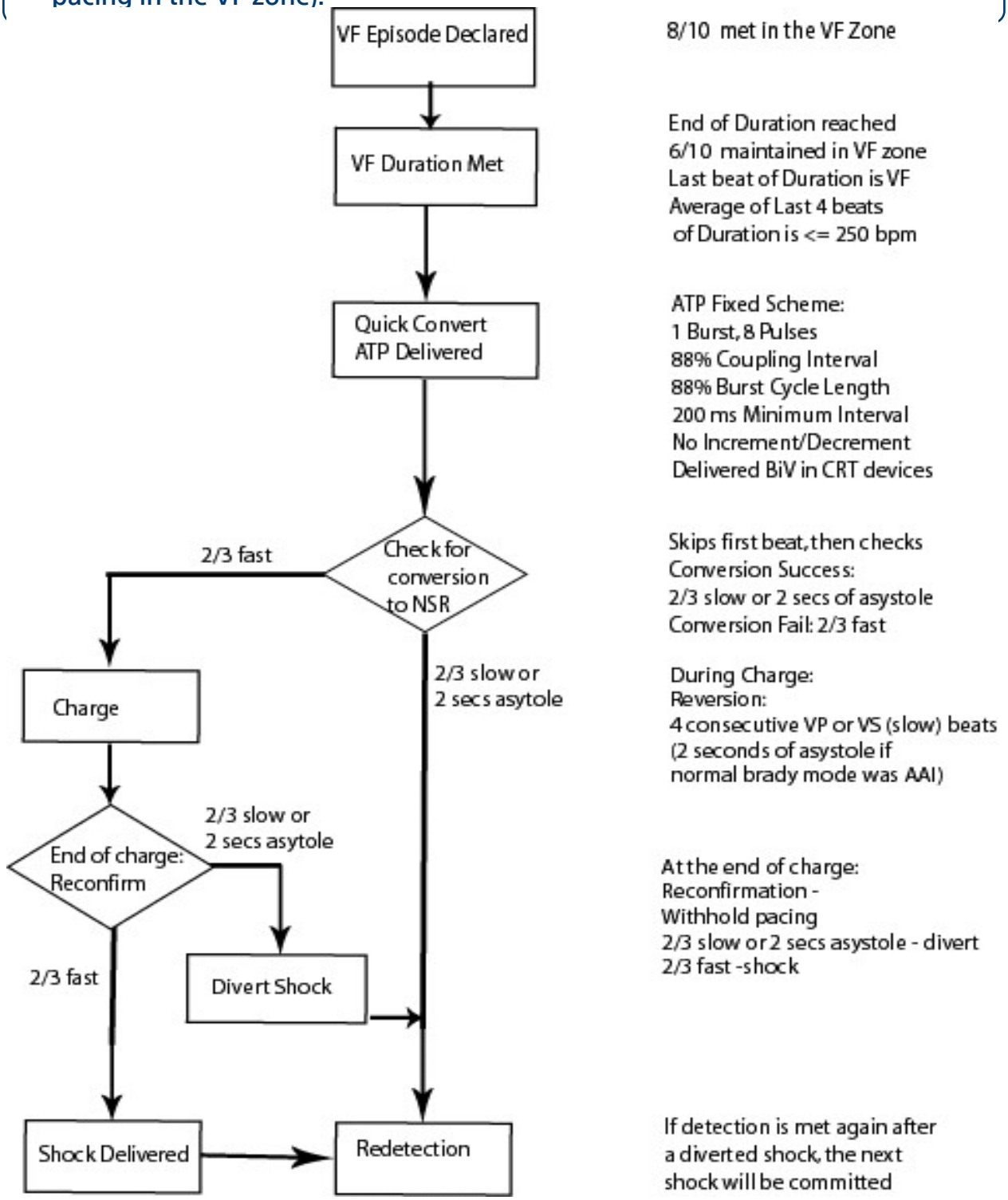
- the PainFree II study demonstrated the effectiveness of anti-tachycardia pacing on tachycardias between 188 and 250 beats/minute, reducing the number of shocks delivered (71% relative risk reduction) without significantly increasing the risk of syncope or sudden death; the Prepare and Relevant studies confirmed these results
- it is recommended to program a burst rather than a ramp (class I) to optimize the success rate (ratio between termination and acceleration)

Once the burst has been delivered, the device analyzes the rhythm: if the arrhythmia persists, charging of the capacitors begins; if the arrhythmia has stopped, charging does not begin.

The device uses the following criteria to assess burst efficacy:

- **the first cycle following the burst is not counted; if a 2-second asystole (no ventricular sensed event) is observed, shock treatment is diverted (not the charge) and the device switches to re-detection**
- **if 2 out of 3 intervals after the burst are faster than the lowest rate threshold (lower limit of the lowest programmed detection zone) , the arrhythmia is considered persistent and charging begins**
- **if 2 out of 3 intervals are slow, shock treatment is diverted (not the charge) and the device switches to redetection**

This figure shows how the Quick Convert algorithm works (anti-tachycardia pacing in the VF zone).



7 ATP burst in the VF zone with acceleration

Patient

- 83-year-old male with severe cardiomyopathy and permanent AF; implanted with an Incepta triple-chamber defibrillator

Summary

- episode classified in the VF zone
- ATP in the VF zone and 31 Joule shock

EGM layout

1 Monomorphic VT detected in the VF zone

2 initial detection satisfied for VF zone (8 cycles out of 10 in FV zone); start of initial VF zone duration (1 second)

3 detection of a VF episode (V-Detect); ventricular rate measured over the 4 cycles preceding the V-Detect marker is below 250 beats/minute (226 bpm)

4 ATP Quick Convert: burst of 8 stimuli at a fixed rate (identical coupling between the last sensed cycle and the first paced cycle, then between the different paced impulses).

5 the first ventricular cycle is sensed in the refractory period following anti-tachycardia pacing (in square brackets); the second is not counted (--)

6 the device analyzes the effectiveness of the pacing sequence: the first 2 cycles following the cycle that was no counted are considered fast (VF-VF); the 2 cycles/3 fast criterion is therefore met and capacitor charging begins (Chrg); when the burst has been ineffective, the start-of-charging marker appears on the trace 300 ms after charging has actually begun; charging begins on the second fast cycle, but the marker may not be visible until the third.

7 accelerated arrhythmia with rapid, low-voltage ventricular cycles

8 end of charge, 500 ms diversion window; shock on second fast cycle

9 effective shock and arrhythmia termination

V-3205: 31 Oct 2014 19:11, VF, A Rate: 30 min^{-1}, V Rate: 224 min^{-1}

Detail

VF Event Onset

Avg A Rate	30 min^{-1}
Avg V Rate	224 min^{-1}
Detection	Rate Only
Template	N/R

At V-Detect

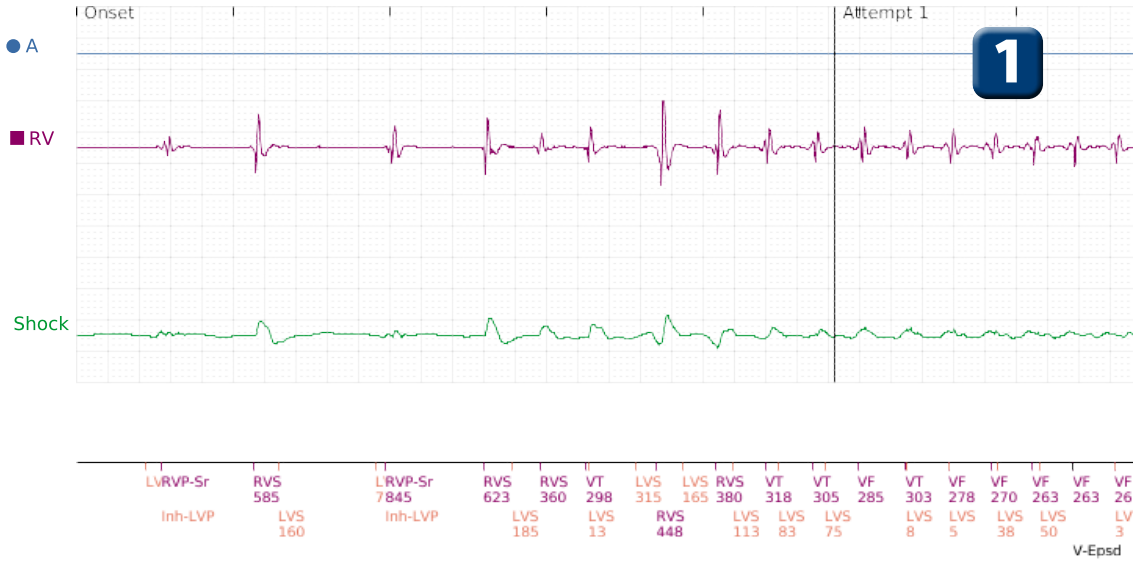
Avg A Rate	30 min^{-1}
Avg V Rate	226 min^{-1}
Rate Zone	VF
Stability	(8 ms, Off)
V>A Rate	(True, Off)
AFib	(False, Off)
RhythmMatch™	N/R
SRD Met	(False, Off)
ATP Timeout	False
Onset Intvl	(68 ms, Off)
Onset %	(11 %, Off)

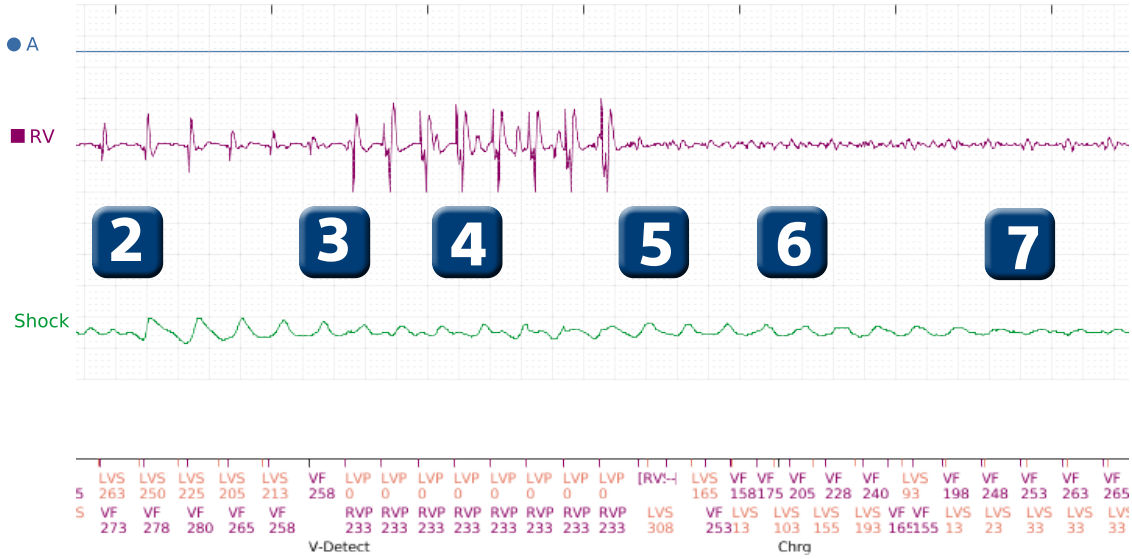
Attempt 1, 31 J V Shock

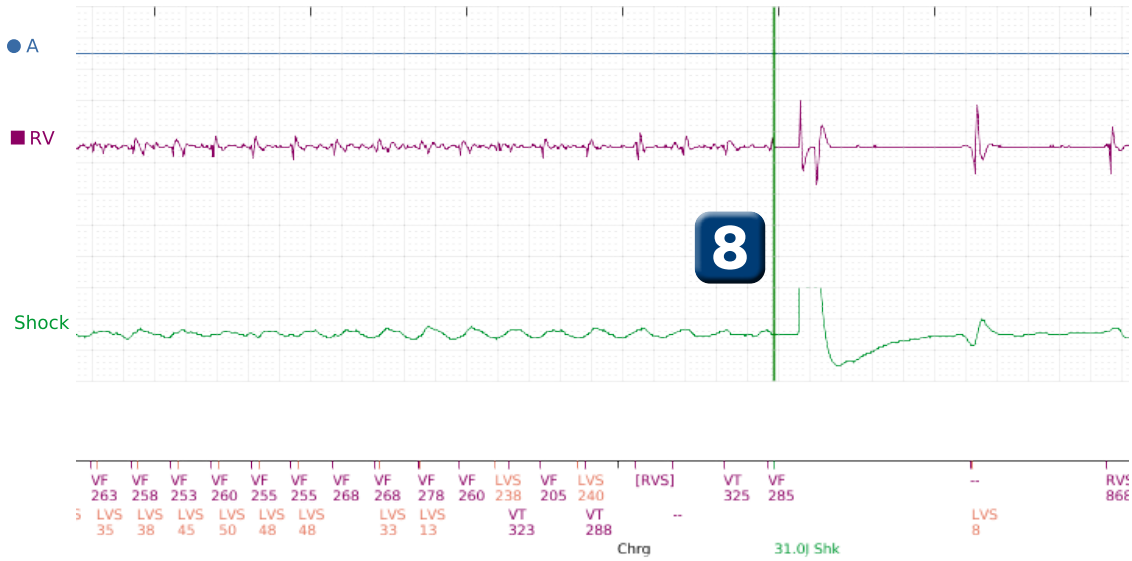
Elapsed Time	00:00:03
VF ATP delivered prior to shock	
Shock Information	
Charge Time	6.0 s
Lead Impedance	74 Ω
Lead Polarity	Initial

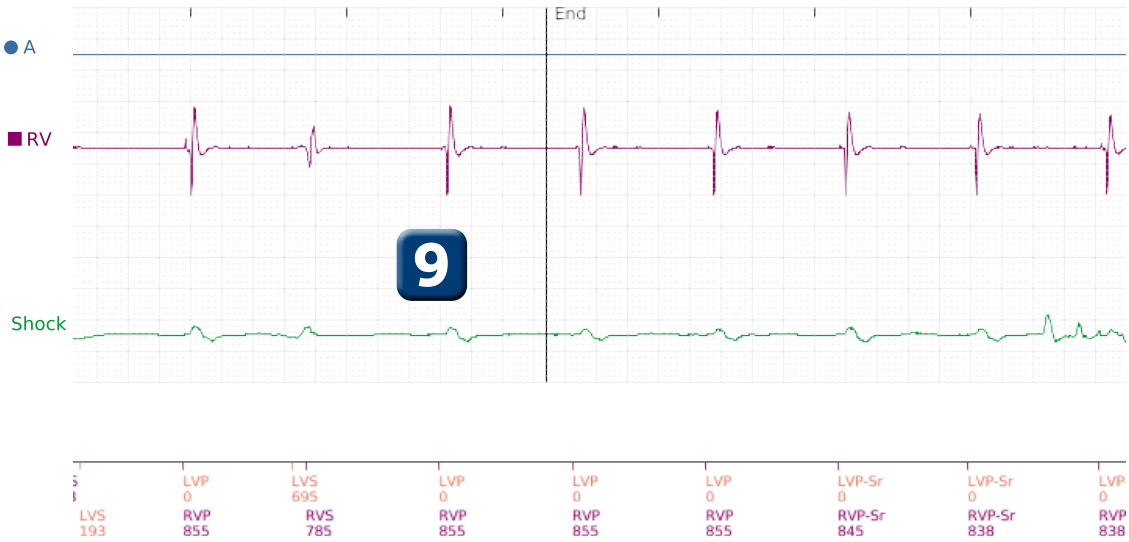
Event Ended 00:00:45

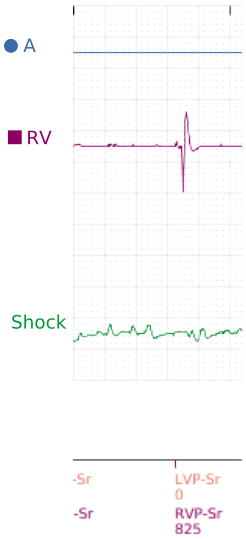
EGM displayed at 25mm per second

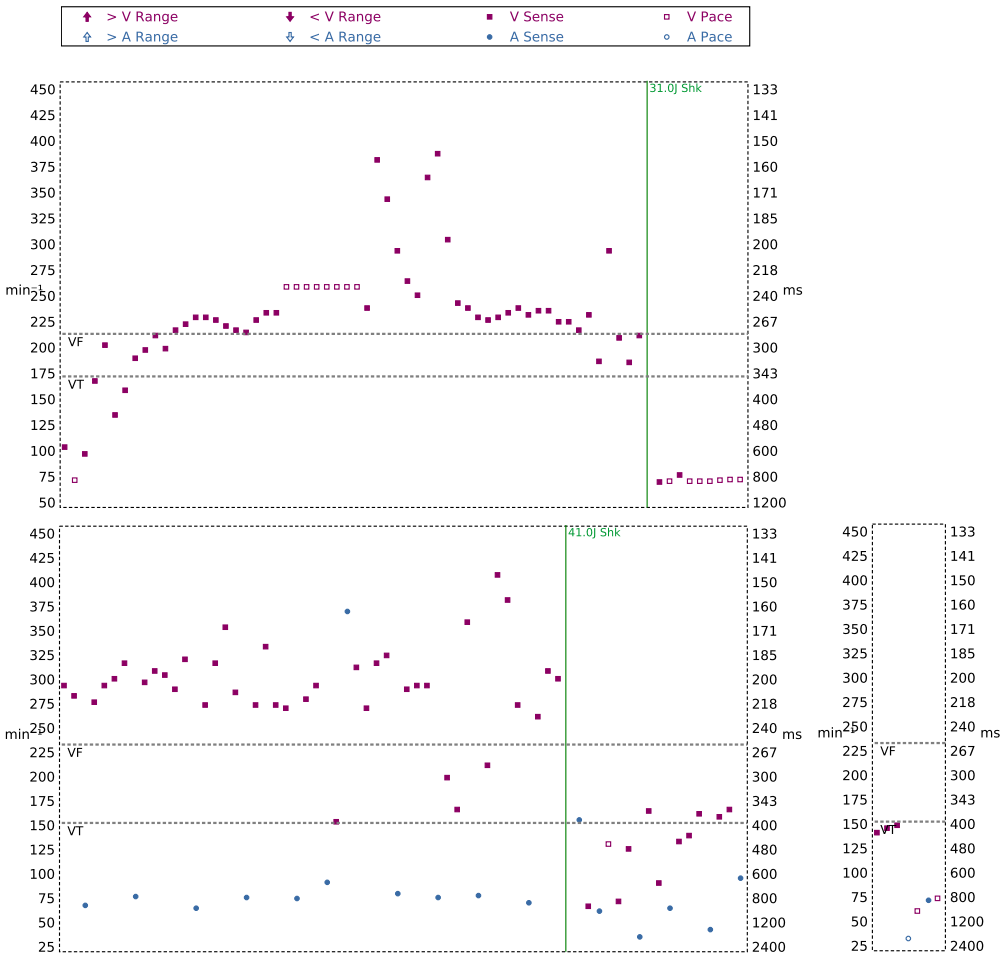



A
RV
2
3
4
5
6
7
Shock
V-Detect
Chrg


A
RV
8
Shock
Chrg
31.0J Shk


End
A
RV
9
Shock
LVS 193
LVP 0
RVP 855
LVS 695
RVS 785
LVP 0
RVP 855
LVP 0
RVP 855
LVP 0
RVP 855
LVP-Sr 0
RVP-Sr 845
LVP-Sr 0
RVP-Sr 838
LVP 0
RVP 838

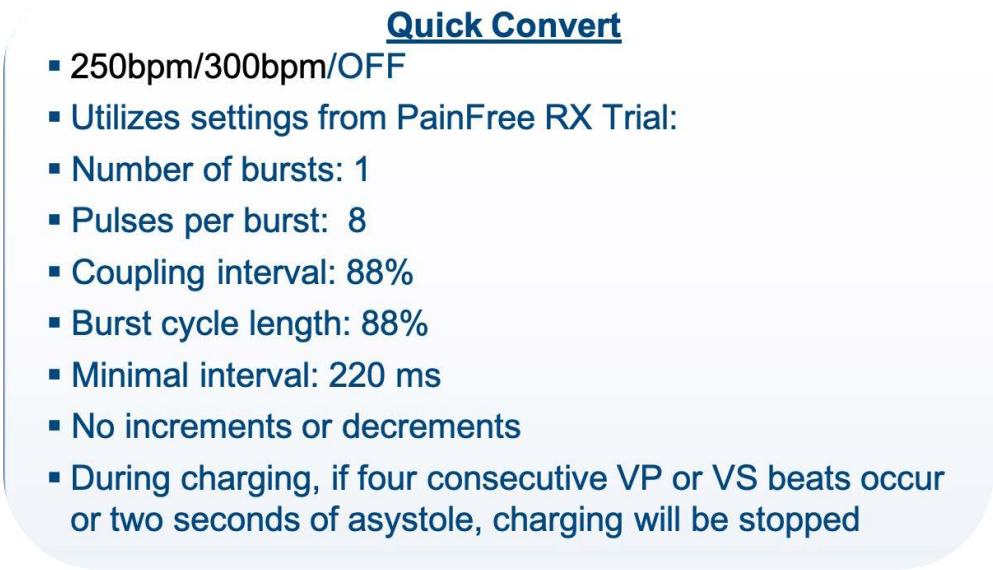

A
RV
Shock
LVP-Sr 0
RVP-Sr 825



Points to remember

- ATP Quick Convert is the anti-tachycardia pacing sequence that can be delivered in the VF zone of a Boston Scientific defibrillator; it is ATP before charge.
- ATP before charging reduces energy consumption; once VF has been diagnosed, ATP is delivered; if VF is reconfirmed after ATP has occurred, capacitor charging begins; if arrhythmia terminates, charging is not initiated; this saves capacitor charging if ATP is effective; on the other hand, if ATP is ineffective, it delays shock delivery by 2 to 3 seconds
- this pacing sequence can only be delivered following initial detection in the VF zone, if the tachycardia sequence does not exceed 250 or 300 beats/minute (programmable on the latest platforms).

- the characteristics of this anti-tachycardia pacing sequence are not programmable: it is a burst of 8 stimuli with an 88% coupling interval
- following this sequence, the device evaluates the effectiveness of the therapy; if at least 2 out of 3 cycles are considered slow, charging is cancelled; conversely, if at least 2 out of 3 cycles are considered fast, charging of the capacitors begins.
- in this example, ATP is not only ineffective but also accelerates tachycardia; a real-life study carried out on Boston Scientific defibrillators showed that, while the effectiveness of a first-line shock for an episode of VF averaged 90%, this success rate fell when the shock was delivered after an anti-tachycardia pacing sequence; one explanation lies in the risk of acceleration, as in this example, from a monomorphic arrhythmia to a very rapid polymorphic arrhythmia, with an increased risk of an ineffective shock; if ineffectiveness or a pro-arrhythmic effect is observed, it is advisable to deprogram the anti-tachycardia pacing sequence



Characteristics of anti-tachycardia pacing in the VF zone: the tachycardia frequency limit up to which ATP will be applied is programmable at either 250 or 300 beats/minute; other parameters are not modifiable (1 burst, 88% coupling, 8 stimuli).

8 undersensing, rate calculation error and ATP burst in the VF zone

Patient

- 43-year-old female with idiopathic VF; implanted with an Autogen dual-chamber defibrillator

Summary

- episode classified in the VF zone
- ATP in the VF zone and 41 Joule shock

EGM layout

1. atrial pacing at the sensor indicated rate and ventricular sensing
2. onset of very rapid polymorphic tachycardia
3. ventricular undersensing; cycle classified VS
4. V-Detect marker; the calculation of the rate found in the summary (225 bpm, i.e. < 250 bpm) is distorted by this undersensing (calculated over the last 4 cycles preceding the V-Detect marker).
5. ATP Quick Convert without ventricular capture
6. Ineffective ATP and capacitor charging
7. shock delivered on the third VF cycle (at the time of the second sensed event, the 500 ms post-charge diversion window has not yet elapsed)
8. effective shock and arrhythmia termination

LATITUDE™ Patient Management - Event Detail Report	Report Created: 18 Jan 2023

Boston Scientific

Date of Birth:
Device: **AUTOGEN EL ICD D176**
Clinic:
Search Tags:
Tachy Mode: **Monitor + Therapy**

Latest Device Transmission: **12 Dec 2022 03:41 CET**
Last Office Interrogation: **16 Dec 2021**
Implant Date:
Patient Group:

V-29: 23 Jun 2018 12:58, VF, A Rate: 98 min^{-1}, V Rate: 343 min^{-1}

Detail

VF Event Onset

Avg A Rate	98 min^{-1}
Avg V Rate	343 min^{-1}
Detection	Rhythm ID
Template	23 Jun 2018 11:24
RhythmMatch™ Threshold	94 %

At V-Detect

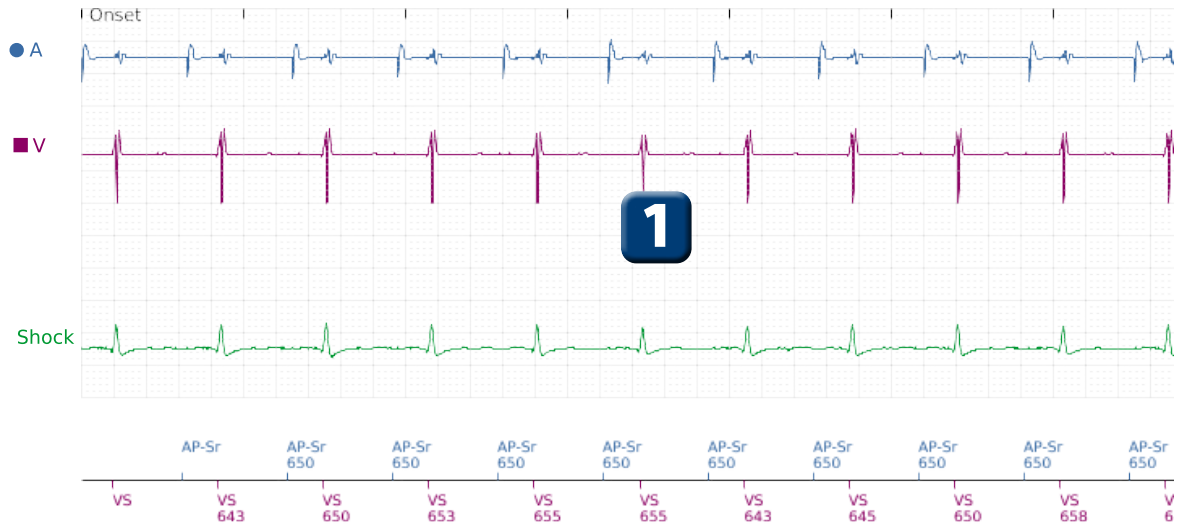
Avg A Rate	127 min^{-1}
Avg V Rate	225 min^{-1}
Rate Zone	VF
Stability	(81 ms, Off)
V>A Rate	(True, Off)
AFib	(False, Off)
RhythmID Correlated	False
RhythmMatch™	Too Fast
SRD Met	(False, Off)
ATP Timeout	False

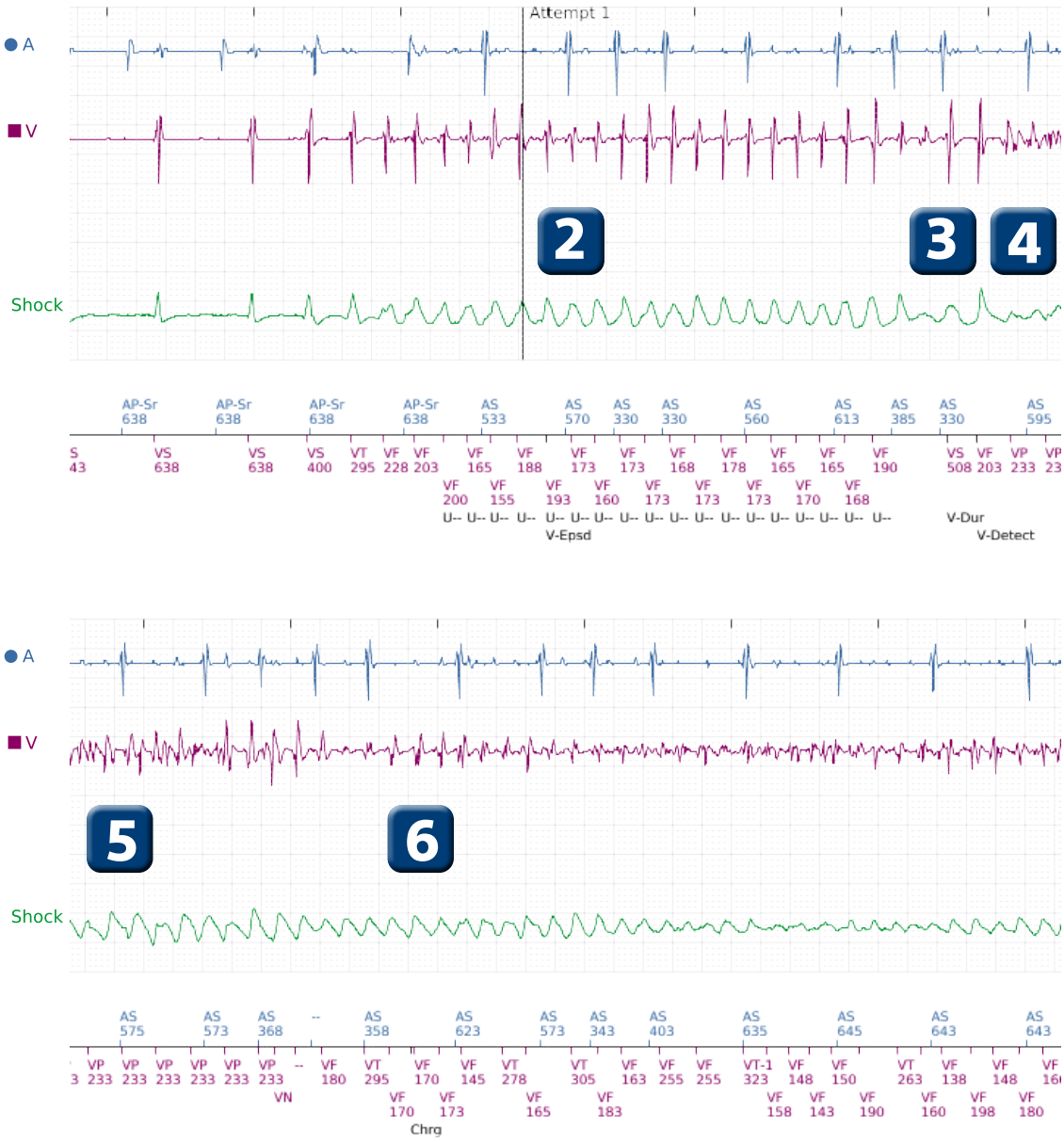
Attempt 1, 41 J V Shock

Elapsed Time	00:00:03
VF ATP delivered prior to shock	
Shock Information	
Charge Time	10.1 s
Lead Impedance	66 Ω
Lead Polarity	Initial

Event Ended 00:00:48

EGM displayed at 25mm per second




Attempt 1
A
V
Shock
2
3
4
AP-Sr 638
AS 533
AS 570
AS 330
AS 560
AS 613
AS 385
AS 595
V-Epsd
V-Dur
V-Detect
5
6
AS 575
AS 573
AS 368
AS 358
AS 623
AS 573
AS 343
AS 403
AS 635
AS 645
AS 643
VN
Chrg


A
V
Shock
7
AS 633
AS 645
AS 563
AS 550
AS 625
AS 633
AS 415
AS 600
AS 643
VT-1 343
VF 163
VF 225
VF 220
VT 285
VF 140
VF 148
VT 290
VF 173
VF 253
VF 158
VF 150
VF 238
VF 140
VF 175
VF 138
VF 145
VF 148
VF 185
VF 180
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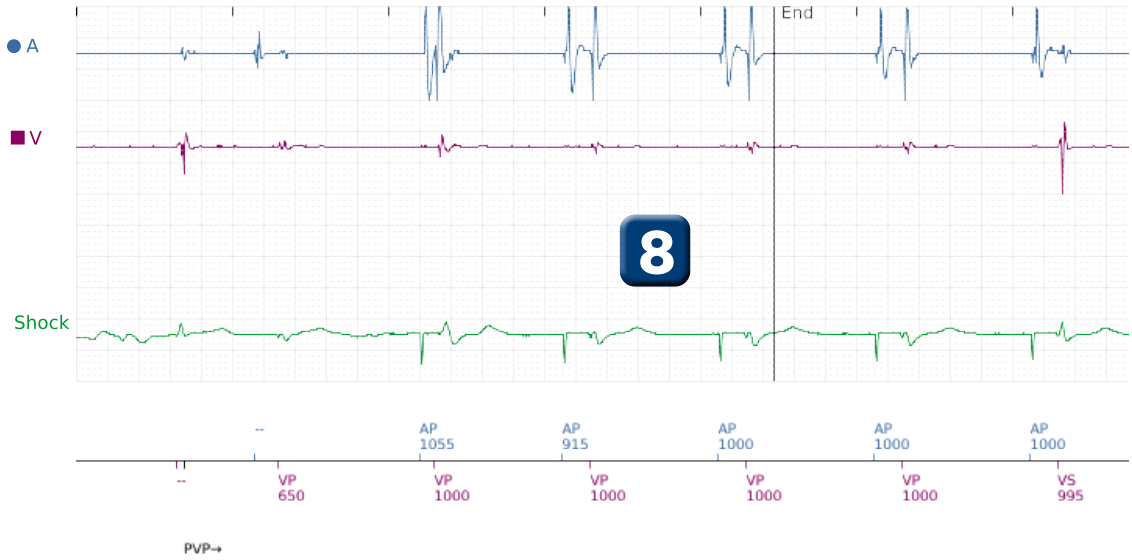
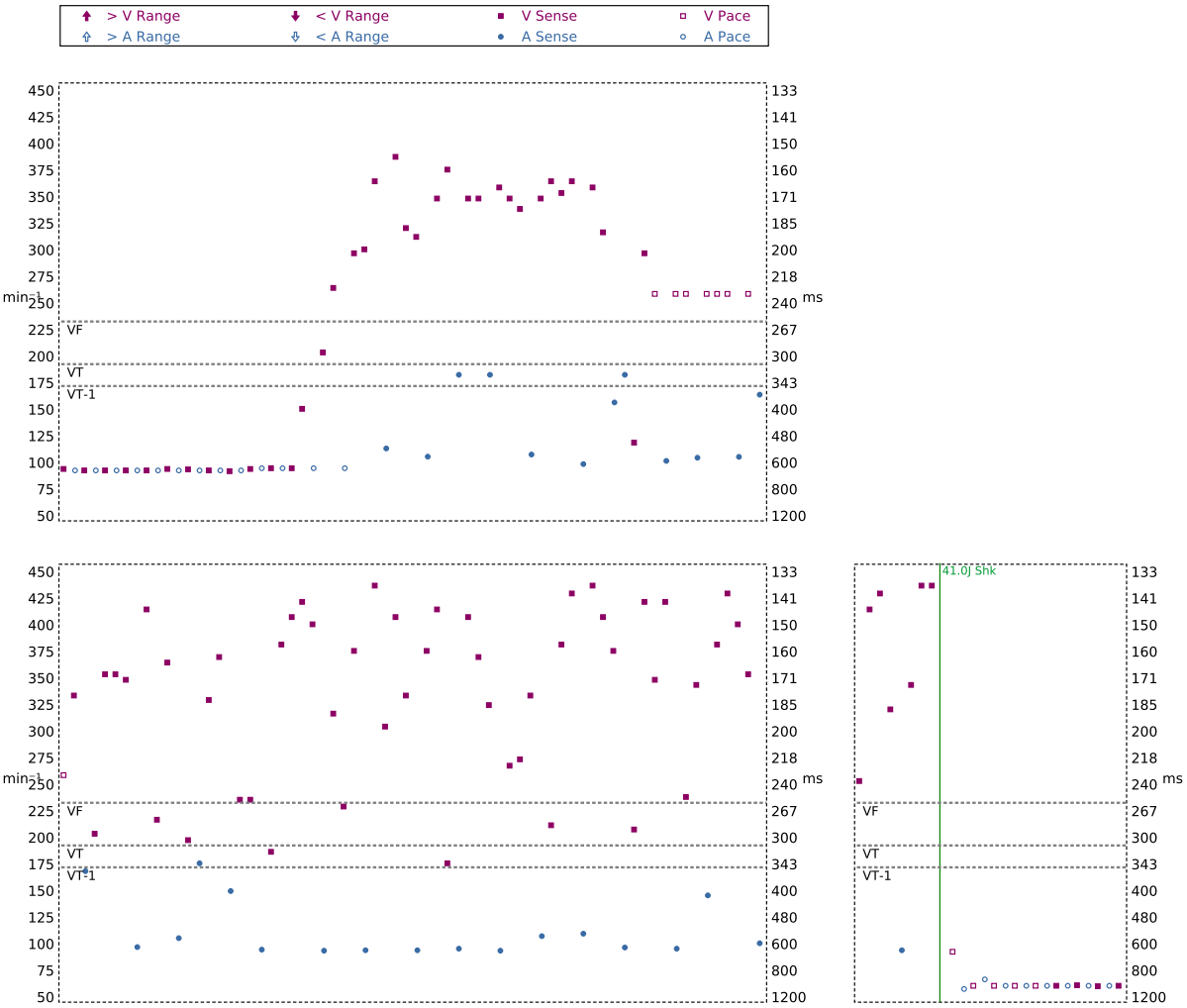
VF 160
VF 143
VF 143
VF 175
VF 140
VF 170
VF 145
VF 188
VF 138
Chrg
41.0J Shk

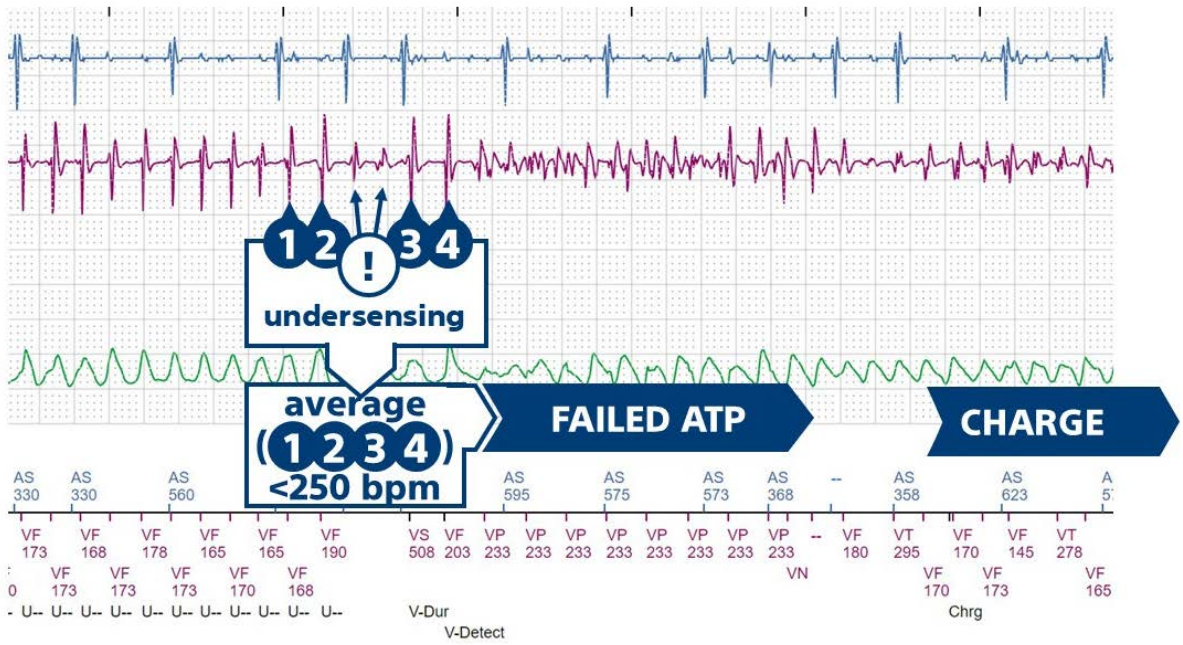

A
V
Shock
End
8
AP 1055
AP 915
AP 1000
AP 1000
AP 1000
VP 650
VP 1000
VP 1000
VP 1000
VP 1000
VS 995
PVP→



Points to remember

- 2 programming options are available for ATP Quick Convert in VF zones: ATP delivered for tachycardias of less than 250 beats/minute or for tachycardias of less than 300 beats/minute.
- in guideline recommendations, the lower limit of the VF zone is 250 beats/minute; programming ATP Quick Convert up to 300 beats/minute could be considered
- the ventricular rate is calculated as the average of the 4 ventricular cycles preceding the V-Detect marker; in this example, ATP is delivered while the ventricular rate is very fast due to the presence of undersensing; this ATP is ineffective (no effective ventricular capture) and does not terminate the arrhythmia

- the level of evidence for the efficacy of ATP for tachycardias above 250 beats/minute is weak; indeed, for this rate range, a majority of ventricular arrhythmias are disorganized and polymorphic and therefore theoretically less likely to be terminated by anti-tachycardia pacing : unpublished data from our center does indicate that there is an interest in performing ATP at these high rates



This figure shows the 4 cycles preceding the V-Detect marker and the undersensing which distorts the rate calculation, this is followed by ATP without ventricular capture; the cycle following the ATP is unclassified (--); the ATP is ineffective, after 2 rapid cycles (VF then VT), capacitor charging begins.

9 Oversensing and anti-tachycardia pacing in the VF zone

Patient

- 73-year-old male implanted with a secondary-prevention, dual-chamber defibrillator for ischaemic cardiomyopathy with sustained VT 8 years ago; box change with implantation of a Teligen defibrillator; multiple episodes of non-sustained VT or VF requiring 1 to 2 ATP sequences noted during a routine consultation

Summary

- initially, the episode is classified in the VF zone
- ATP is delivered, the shock is diverted due to reconfirmation failure
- a second episode is diagnosed in the VT zone; a burst of ATP is delivered

EGM layout

1. AP-Sr VP-Sr cycle (Sr for sensor, meaning that the rate is set by the sensor: rate response)
2. oversensing by the ventricular channel with signals of variable amplitude and morphology in the VT or VF zone; the shock channel shows no oversensing and allows differentiation of spontaneous ventricular activity; atrial pacing is at the sensor indicated rate ; the atrial rate is variable because it is influenced by ventricular oversensing
3. VF counter is filled (V-Epsd)
4. oversensing is intermittent and at the end of the duration, the rhythm is considered sinus; no therapy is delivered
5. new ventricular oversensing
6. the VF counter is filled and at the end of the duration, the first therapy is delivered.
7. during ATP (Quick Convert), ventricular capture is intermittent (2 effective stimuli, 6

ineffective stimuli)

8 oversensing continues following ATP and capacitor charging begins (the first cycle following the ATP sequence is not counted; 2 out of 3 cycles are then classified as VT or VF, explaining the start of capacitor charging).

9 when oversensing stops, the charge is diverted (the 6/10 rapid cycle criterion is no longer met)

10 resumption of oversensing

11 VT counter filled (V-Detect)

12 an ATP sequence is delivered; ventricular stimuli do not capture

Event V-13386: 24 Aug 2011 07:22

VF Event Onset
Avg A Rate: 56 bpm
Avg V Rate: 321 bpm
Detection: Rhythm ID

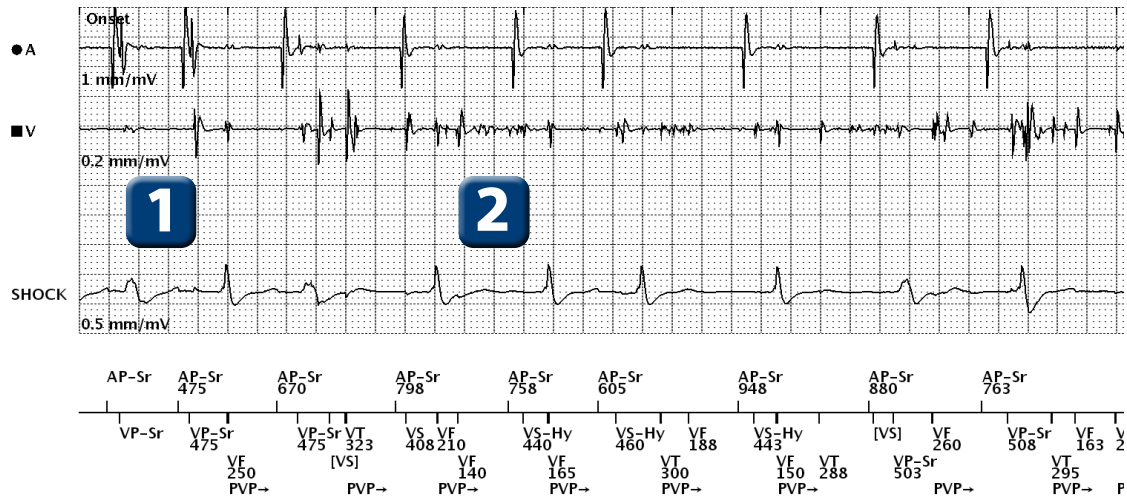
At V-Detect
Avg A Rate: 54 bpm
Avg V Rate: 111 bpm
Rate Zone: VF
Stability: (258 ms, Off)
V>A Rate: (True, Off)
AFib: (False, Off)
RhythmID Correlated: False
SRD Met: (False, Off)
ATP Timeout: False

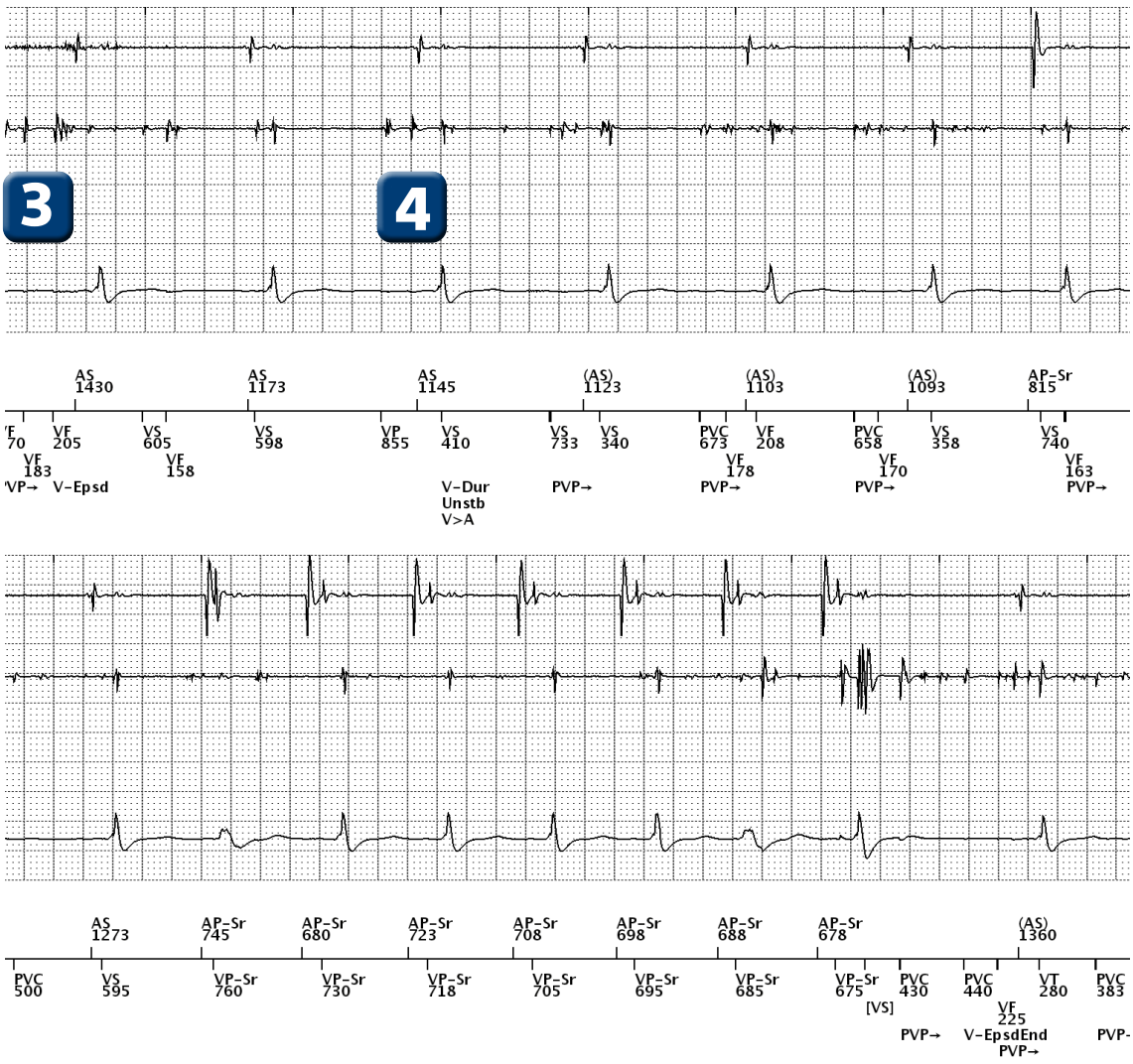
Attempt 1, 41 J V Shock
Elapsed Time: 00:00:03
Aborted Attempt
VF ATP delivered, no shock attempted due to fail to reconfirm

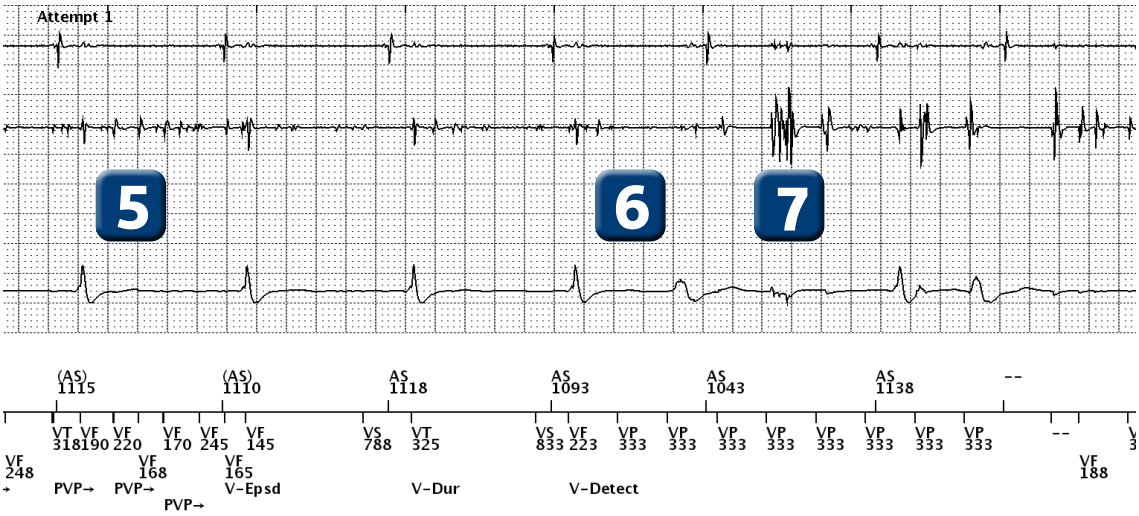
At V-Detect
Avg A Rate: 58 bpm
Avg V Rate: 199 bpm
Rate Zone: VT
ATP Timeout: False

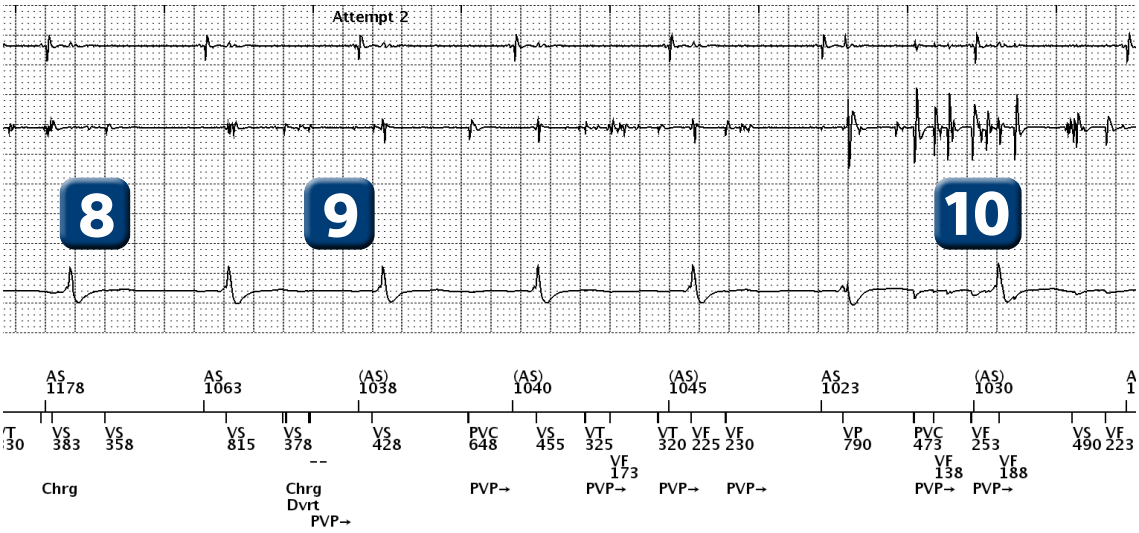
Attempt 2, Burst V ATP
Elapsed Time: 00:00:15
ATP Information:
Number of Bursts: 1

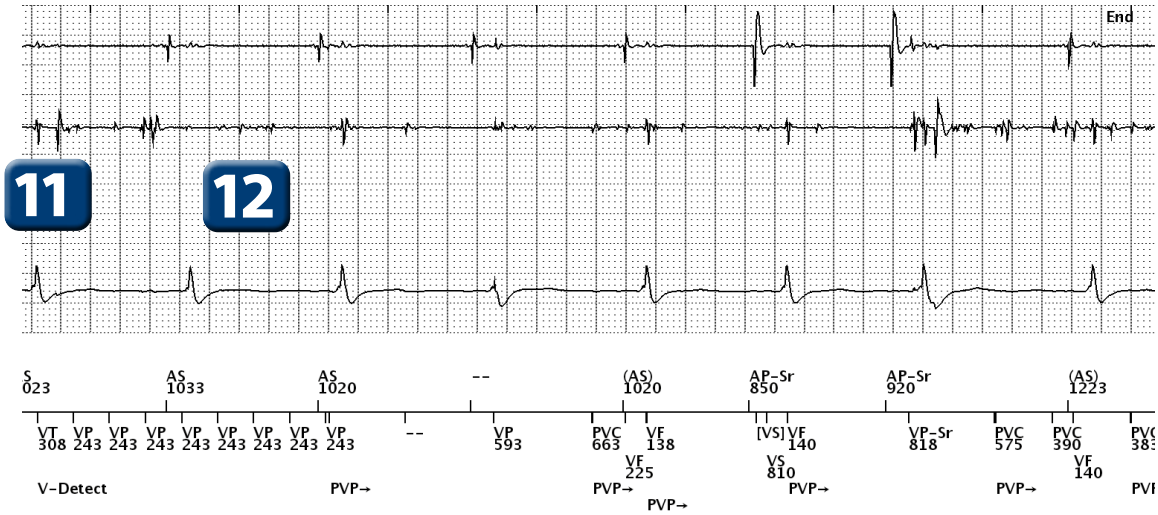
Event Ended 00:00:28

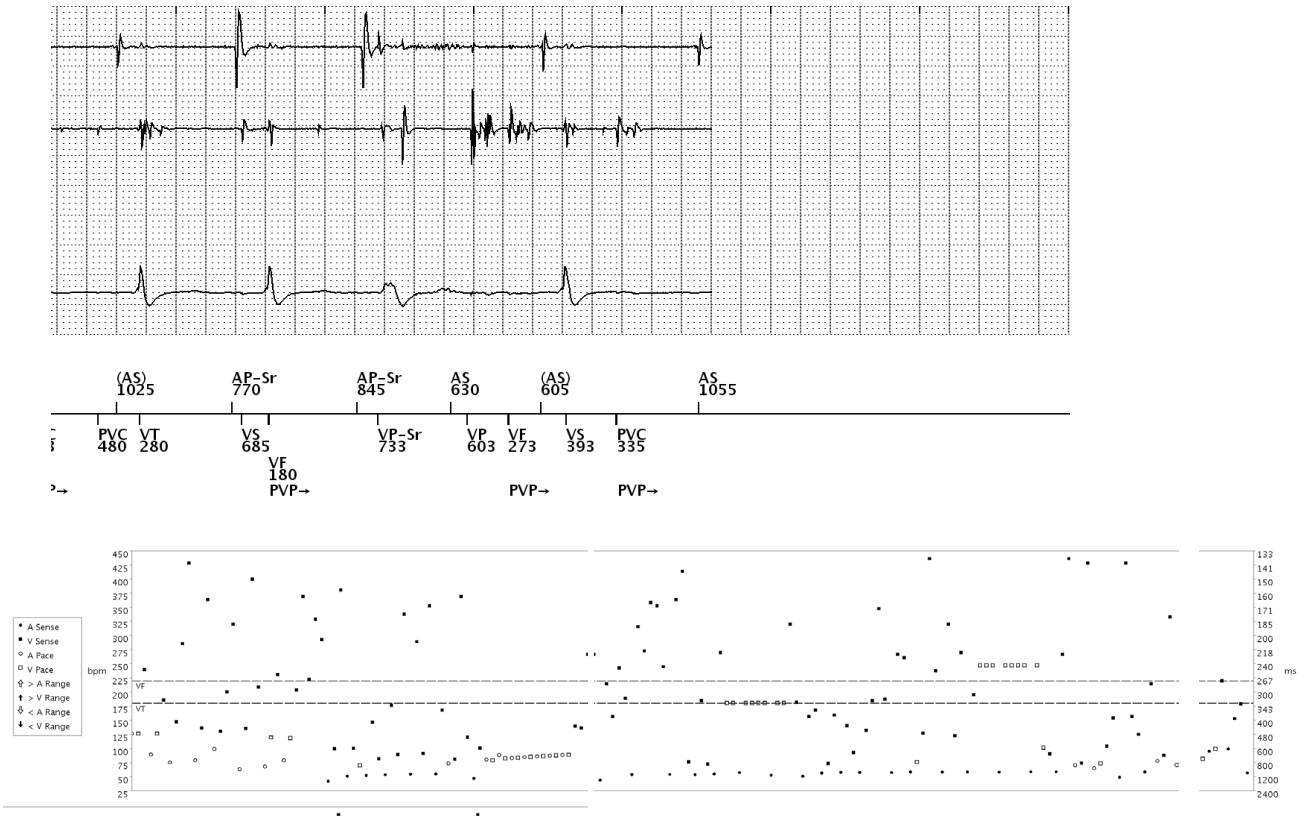



3
4
AS 1430
AS 1173
AS 1145
(AS) 1123
(AS) 1103
(AS) 1093
AP-Sr 815
F 70
VF 205
VF 183
VP→
V-Epsd
VS 605
VF 158
VS 598
VP 855
VS 410
V-Dur
Unstb
V>A
VS 733
VS 340
PVP→
PVC 673
VF 208
VF 178
PVP→
PVC 658
VS 358
VF 170
PVP→
VS 740
VF 163
PVP→
AS 1273
AP-Sr 745
AP-Sr 680
AP-Sr 723
AP-Sr 708
AP-Sr 698
AP-Sr 688
AP-Sr 678
(AS) 1360
PVC 500
VS 595
VP-Sr 760
VP-Sr 730
VP-Sr 718
VP-Sr 705
VP-Sr 695
VP-Sr 685
VP-Sr 675
[VS]
PVC 430
PVP→
PVC 440
VF 225
V-EpsdEnd
PVP→
VT 280
PVC 383
PVP-


Attempt 1
5
6
7
(AS) 1115
(AS) 1110
AS 1118
AS 1093
AS 1043
AS 1138
VT 318 VF 190 VF 220 VF 170 VF 245 VF 145 VS 788 VT 325 VS 833 VF 223 VP 333 VP 333 VP 333 VP 333 VP 333 VP 333 VP 333 VP 333
VF 248
VF 168
VF 165
VF 188
PVP→
PVP→
PVP→
V-Epsd
V-Dur
V-Detect


Attempt 2
8
9
10
AS 1178
AS 1063
(AS) 1038
(AS) 1040
(AS) 1045
AS 1023
(AS) 1030
VS 383 VS 358 VS 815 VS 378 VS 428 PVC 648 VS 455 VT 325 VT 320 VF 225 VF 230 VP 790 PVC 473 VF 253 VS 490 VF 223
VF 173
VF 138
VF 188
Chrg
Chrg
Dvrt
PVP→
PVP→
PVP→
PVP→
PVP→
PVP→
PVP→

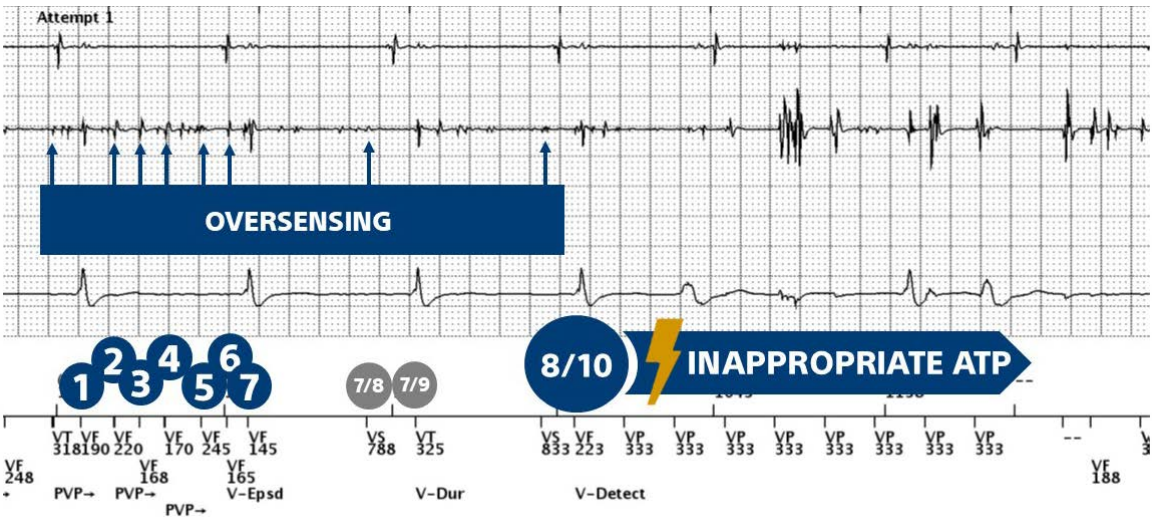

End
11
12
AS 1033
AS 1020
(AS) 1020
AP-Sr 850
AP-Sr 920
(AS) 1223
VT 308 VP 243 VP 243 VP 243 VP 243 VP 243 VP 243 VP 243 VP 243 VP 593 PVC 663 VF 138 VF 225 [VS] VF 140 VS 810 VP-Sr 818 PVC 575 PVC 390 VF 140
V-Detect
PVP→
PVP→
PVP→
PVP→
PVP→
PVP→



Points to remember

- this tracing shows an example of inappropriate therapy due to lead dysfunction; a very rapid pacing sequence is delivered, illustrating one of the potential risks of systematically programming a pacing sequence for rates up to 300 beats/minute; for these very high heart rates, there is an increased risk of inappropriate treatment by rapid pacing of non-physiological, false-positive tachycardias (lead fracture, oversensing of P, R or T wave, electromagnetic interference)
- in patients with ischemic cardiomyopathy, VT can be triggered by a rapid ventricular pacing protocol; this perfectly explains the potential pro-arrhythmogenic effect of inappropriate anti-tachycardia pacing , particularly when the pacing protocol is very aggressive in the VF zone; the pro-arrhythmogenic risk has been particularly well documented for anti-tachycardia pacing and for low-amplitude shocks (much more so than for maximum-amplitude shocks, which are less arrhythmogenic)

- in this example, the pro-arrhythmogenic risk is reduced, since ventricular capture is not always effective due to the lead dysfunction
- there is now a consensus favoring treatment with anti-tachycardia pacing over shocks for organized ventricular arrhythmias; in fact, many episodes diagnosed as VF by the defibrillator on the basis of a rate > 200 beats/minute correspond to rapid monomorphic VT, which can be effectively treated by pacing; anti-tachycardia pacing is painless and reduces battery consumption and should therefore be the preferred first-line treatment for organized ventricular arrhythmias, even when they are very rapid
- on the other hand, systematic programming of anti-tachycardia pacing for rates of up to 300 beats/minute has not been shown to be effective and carries a pro-arrhythmogenic risk if the therapy is inappropriate



Cette figure montre la surdétection et la stimulation ventriculaire rapide en zone de FV avec capture intermittente

10 Anti-tachycardia pacing in the VT zone

Patient

- 62-year-old male implanted with a Momentum CRT defibrillator

Summary

- episode classified in the VT zone
- 1 burst

EGM layout

1. spontaneous atrial rhythm and biventricular pacing
2. regular, monomorphic ventricular tachycardia (atrioventricular dissociation) diagnosed in the VT zone
3. V-Epsd after 8 out of 10 cycles in VT or VT-1 zone
4. start of initial VT zone duration (12 seconds)
5. diagnosis of sustained VT (V-Detect) at end of duration (V>A)
6. burst of 10 complexes at fixed cycle length; biventricular pacing
7. effective burst and arrhythmia termination

V-56: 15 Mar 2022 20:03, VT, A Rate: 78 min^{-1}, V Rate: 180 min^{-1}

Detail

VT Event Onset

Avg A Rate	78 min^{-1}
Avg V Rate	180 min^{-1}
Detection	Rhythm ID
Template	N/R
RhythmMatch™ Threshold	94 %

At V-Detect

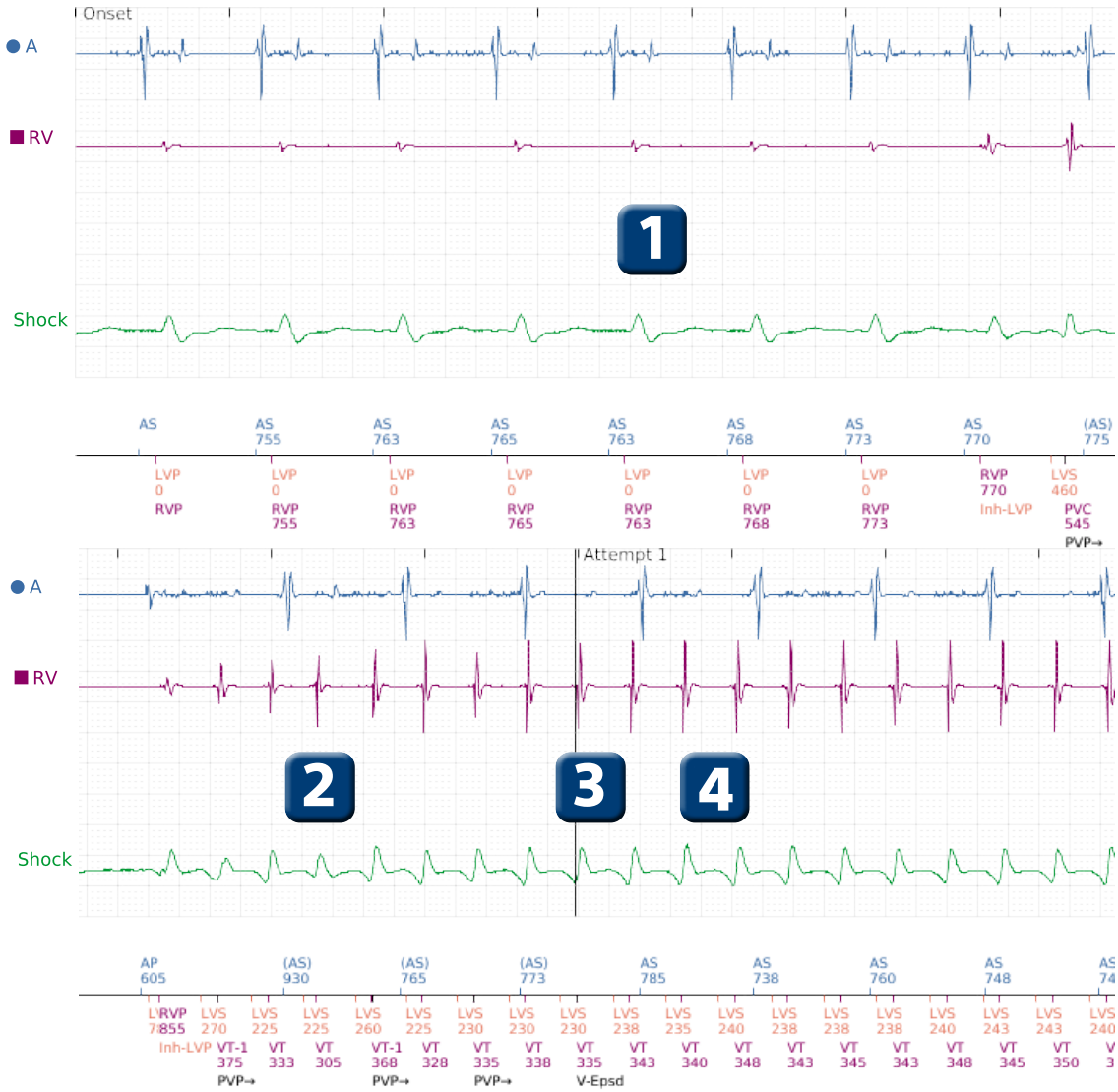
Avg A Rate	85 min^{-1}
Avg V Rate	173 min^{-1}
Rate Zone	VT
Stability	4 ms
V>A Rate	True
AFib	False
RhythmID Correlated	False
RhythmMatch™	N/R
SRD Met	(False, Off)
ATP Timeout	False

Attempt 1, Burst V ATP

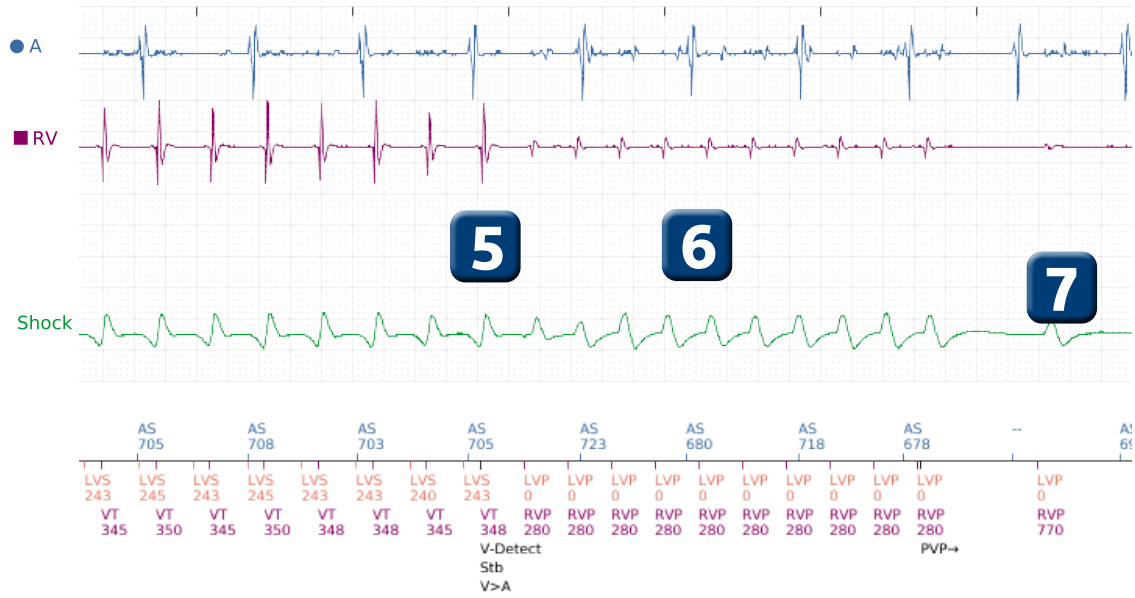
Elapsed Time	00:00:13
ATP Information	
Number of Bursts	1

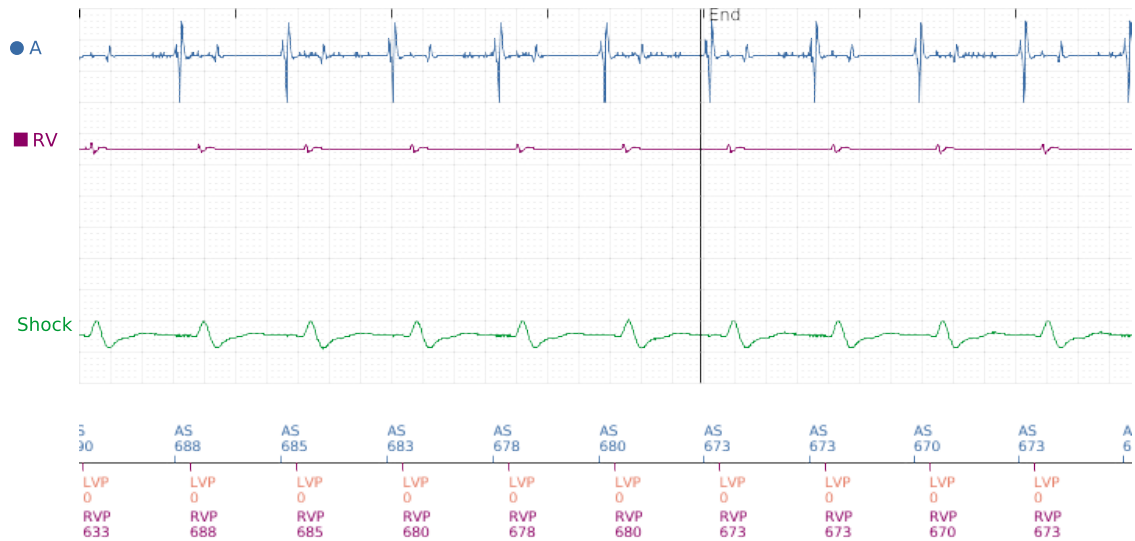
Event Ended 00:00:27

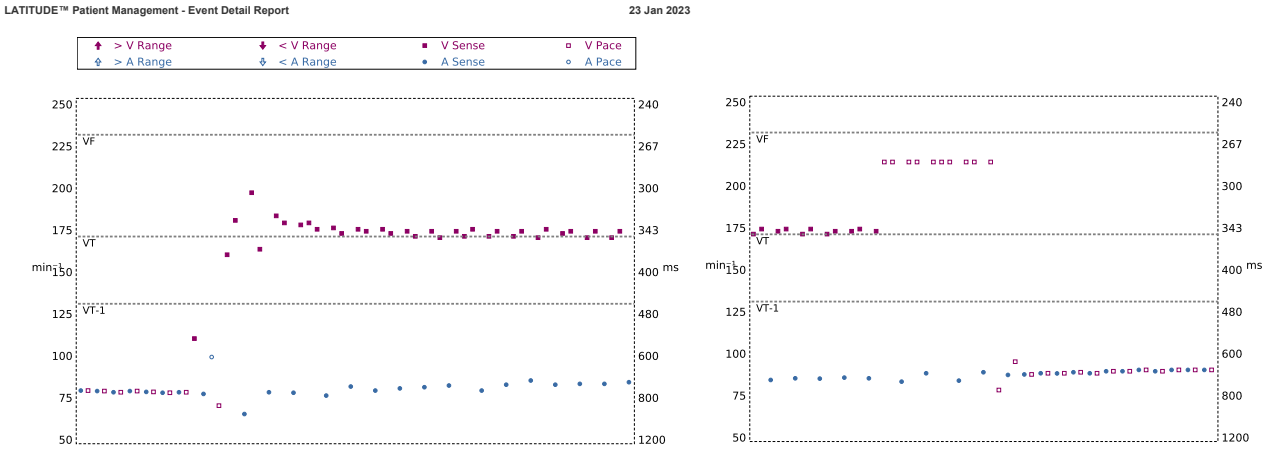
EGM displayed at 25mm per second




A
RV
Shock
AS 735 AS 755 AS 728 AS 710 AS 728 AS 720 AS 720 AS 715 AS 715
LVS 243 LVS 240 LVS 240 LVS 238 LVS 243 LVS 240 LVS 243 LVS 240 LVS 245 LVS 238 LVS 243 LVS 240 LVS 245 LVS 240 LVS 245 LVS 240 LVS 245 LVS 240 LVS 243
VT 345 VT 353 VT 345 VT 350 VT 343 VT 350 VT 345 VT 350 VT 345 VT 353 VT 343 VT 348 VT 345 VT 353 VT 345 VT 353 VT 345 VT 350 VT 345 VT 348


A
RV
5
6
7
Shock
AS 705 AS 708 AS 703 AS 705 AS 723 AS 680 AS 718 AS 678
LVS 243 LVS 245 LVS 243 LVS 245 LVS 243 LVS 243 LVS 240 LVS 243 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0
VT 345 VT 350 VT 345 VT 350 VT 348 VT 348 VT 345 VT 348 RVP 280 RVP 280 RVP 280 RVP 280 RVP 280 RVP 280 RVP 280 RVP 280 RVP 280 RVP 280
V-Detect
Stb
V>A
PVP→
RVP 770

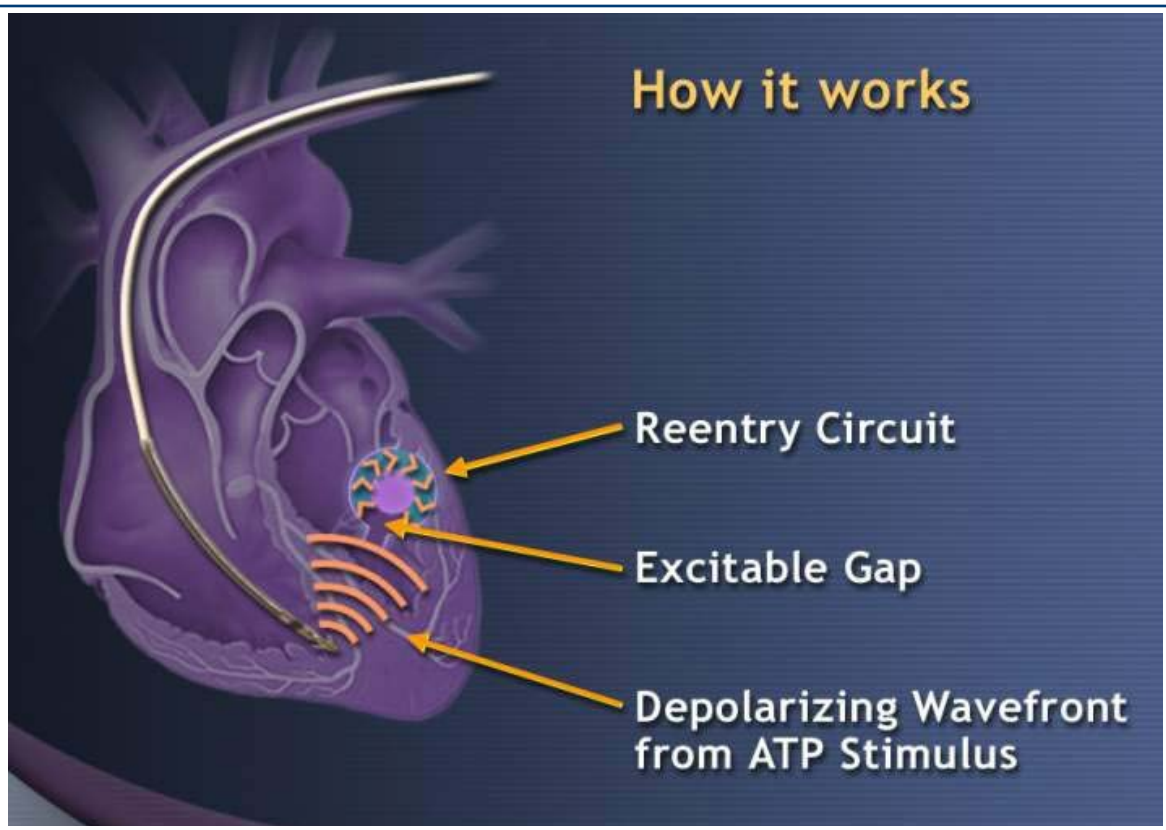

End
A
RV
Shock
AS 688 AS 685 AS 683 AS 678 AS 680 AS 673 AS 673 AS 670 AS 673
LVP 0 RVP 688 LVP 0 RVP 685 LVP 0 RVP 680 LVP 0 RVP 678 LVP 0 RVP 680 LVP 0 RVP 673 LVP 0 RVP 673 LVP 0 RVP 670 LVP 0 RVP 673



Points to remember

- a priority when programming an implantable defibrillator is to reduce the number of shocks delivered as much as possible without compromising patient safety; the ideal scenario is to interrupt the tachycardia with the least aggressive and least painful therapy possible; anti-tachycardia pacing is therefore the preferred first-line therapy for organized reentrant tachycardias since it is less painful and reduces battery consumption compared to shocks.
- the basic principle of anti-tachycardia pacing is based on the existence of an excitation window in a reentrant circuit during which rapid pacing can generate a new activation front that collides with the tachycardia circuit and interrupts it; the ventricle must therefore be paced at a higher rate than the tachycardia
- the efficacy of this type of therapy has been demonstrated for a wide range of ventricular tachycardia rates up to 240 beats/minute; anti-tachycardia pacing terminates around 90% of ventricular tachycardias with rates below 200 beats/minute, with a moderate risk of acceleration on the order of 1 to 5%.
- these observations have repositioned the implantable «defibrillator» as a first-line treatment for arrhythmias through rapid pacing, with the possibility of defibrillation as a back-up only.

- one or more ATP sequences can be programmed empirically, without the need for prior electrophysiological testing of efficacy
- this patient presented with numerous episodes of VT effectively treated by anti-tachycardia pacing; rapid and effective treatment by pacing enabled the patient to remain asymptomatic with a preserved quality of life while preserving the battery's longevity



This figure shows how antitachycardia pacing works. Scan the QR code to see a Youtube video made by Dr. Joshua Cooper clearly explaining how ATP works with animations.

11 Anti-tachycardia pacing in the VT zone and post-detection duration

Patient

- 73-year-old woman implanted with a Resonate CRT defibrillator

Summary

- episode classified in the VT zone
- 4 bursts + 3 ramps

EGM

1 spontaneous rhythm in the atrium and biventricular pacing

2 regular, monomorphic ventricular tachycardia (atrioventricular dissociation) diagnosed in the VT zone

3 V-Epsd after 8 out of 10 cycles in the VT zone and start of initial VT zone duration (12 seconds)

4 diagnosis of sustained VT (V-Detect) at end of duration (V>A)

5 burst of 10 complexes at fixed rate; biventricular pacing

6 effective burst and arrhythmia termination

7 restart of an identical VT before the V-EpsdEnd marker

8 criterion 8/10 verified and start of post-detection time (1 second)

9 end of duration, burst (considered by the device as the second burst for the same episode)

10 effectve burst, but rapid VT recurrence

11 third burst

12 fourth burst

13 first ramp (pacing with 10 ms increments between stimuli; shortest cycle length limited to 200 ms)

14 second ramp

15 third ramp

16 NSVT (criterion 8/10 not met)

V-71: 27 May 2021 15:39, VT, A Rate: 98 min^{-1}, V Rate: 207 min^{-1}

Detail

VT Event Onset

Avg A Rate	98 min^{-1}
Avg V Rate	207 min^{-1}
Detection	Rhythm ID
Template	04 Apr 2021 12:27
RhythmMatch™ Threshold	94 %

At V-Detect

Avg A Rate	103 min^{-1}
Avg V Rate	198 min^{-1}
Rate Zone	VT
Stability	2 ms
V>A Rate	True
AFib	False
RhythmID Correlated	False
RhythmMatch™	70 %
SRD Met	(False, Off)
ATP Timeout	False

Attempt 1, Burst V ATP

Elapsed Time	00:00:30
ATP Information	
Number of Bursts	4

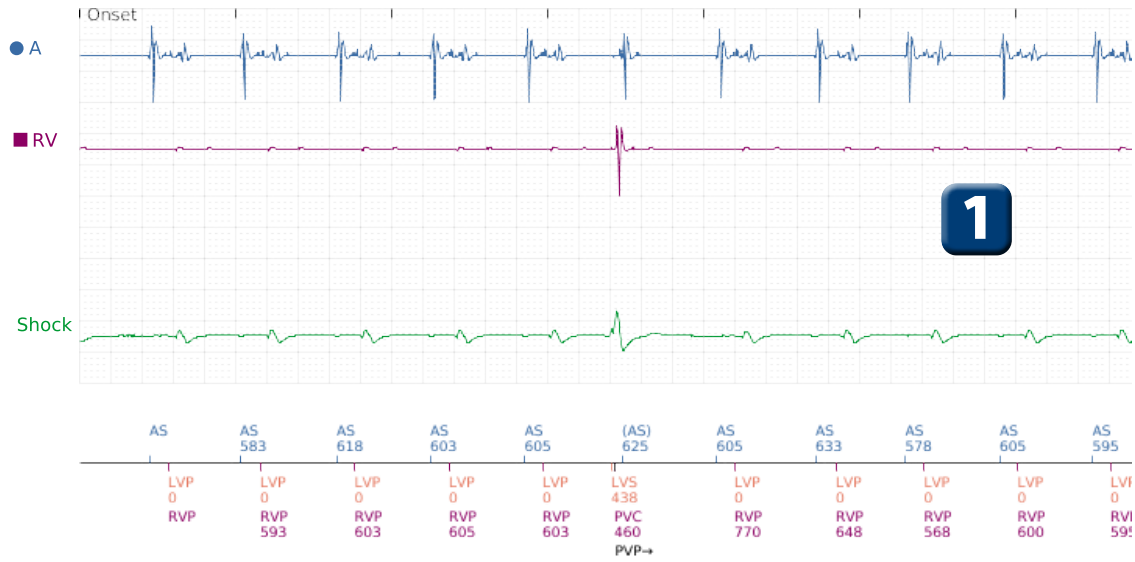
At V-Detect

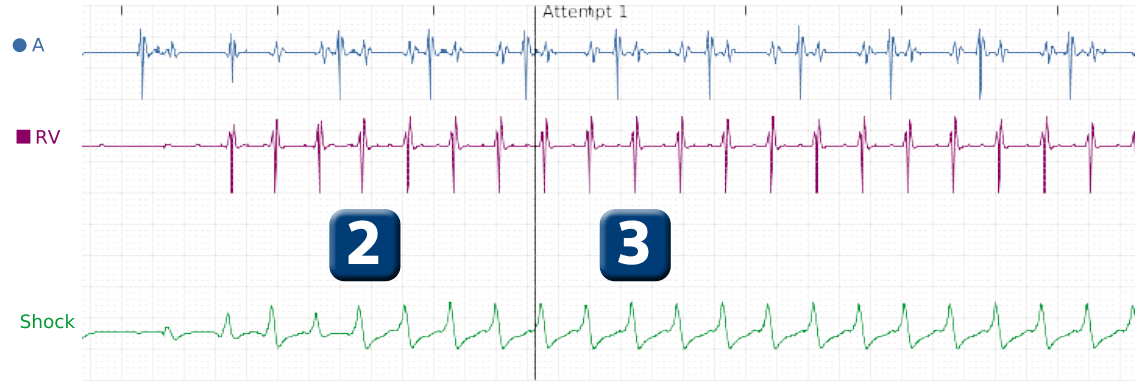
Avg A Rate	98 min^{-1}
Avg V Rate	200 min^{-1}
Rate Zone	VT
ATP Timeout	False

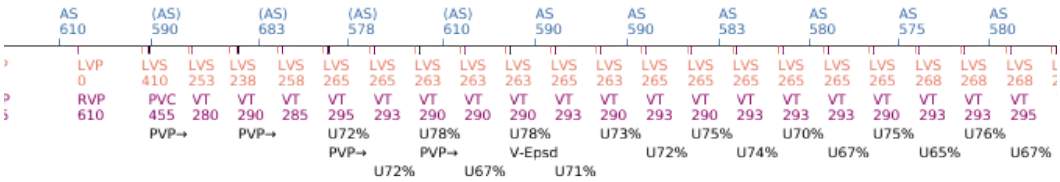
Attempt 2, Ramp V ATP

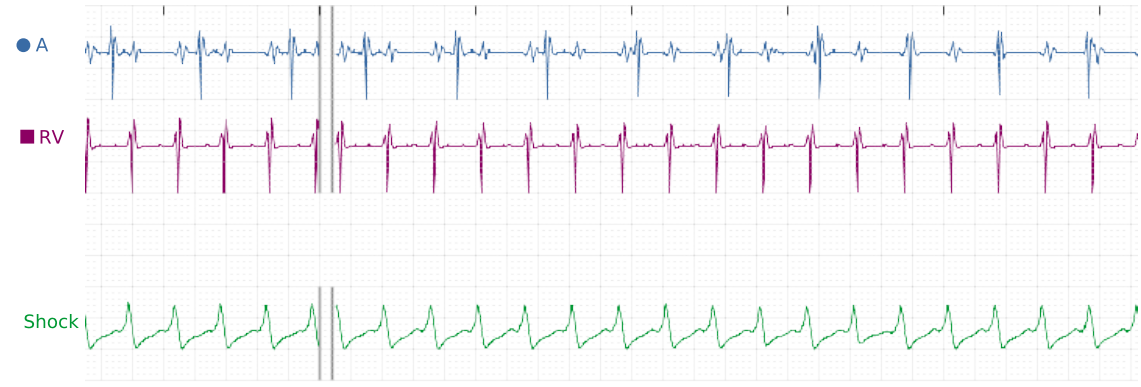
Elapsed Time	00:01:14
ATP Information	
Number of Bursts	3

Event Ended 00:01:57




Attempt 1
A
RV
2
3
Shock


AS 610 (AS) 590 (AS) 683 (AS) 578 (AS) 610 AS 590 AS 590 AS 583 AS 580 AS 575 AS 580
LVP 0 RVP 610
LVS 410 LVS 253 LVS 238 LVS 258 LVS 265 LVS 265 LVS 263 LVS 263 LVS 263 LVS 265 LVS 263 LVS 265 LVS 265 LVS 265 LVS 265 LVS 265 LVS 268 LVS 268 LVS 268
PVC 455 VT 280 VT 290 VT 285 VT 295 VT 293 VT 290 VT 290 VT 290 VT 293 VT 290 VT 293 VT 290 VT 293 VT 293 VT 293 VT 290 VT 293 VT 293 VT 295
PVP→ PVP→ U72% U78% U78% U73% U75% U70% U75% U76%
PVP→ V-Epsd U72% U74% U67% U65% U67%
U72% U67% U71%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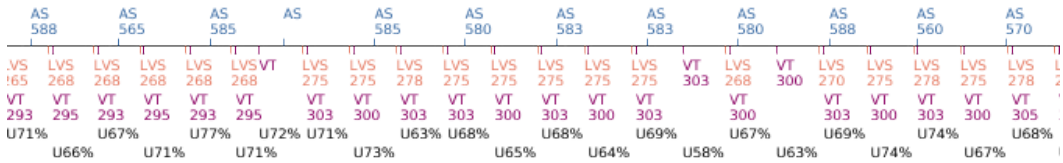
RV
Shock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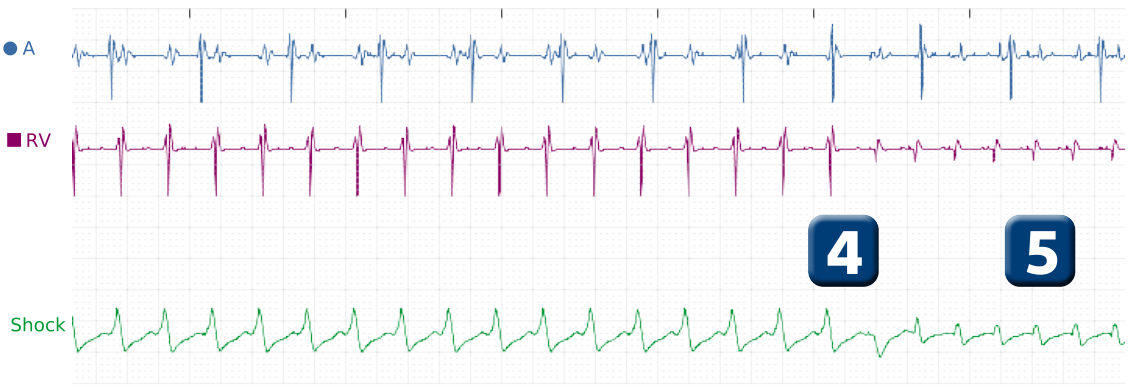
LVS 268 LVS 268 LVS 268 LVS 268 LVS 268 LVS VT LVS 275 LVS 275 LVS 278 LVS 275 LVS 275 LVS 275 LVS 275 LVS 275 VT 303 LVS 268 VT 300 LVS 270 LVS 275 LVS 278 LVS 275 LVS 278
VT 293 VT 295 VT 293 VT 295 VT 293 VT 295 VT 303 VT 300 VT 303 VT 303 VT 300 VT 303 VT 303 VT 303 VT 300 VT 303 VT 303 VT 303 VT 300 VT 305
U71% U67% U77% U72% U71% U73% U63% U68% U65% U68% U64% U69% U58% U67% U63% U69% U74% U67% U68%
U66% U71% U71%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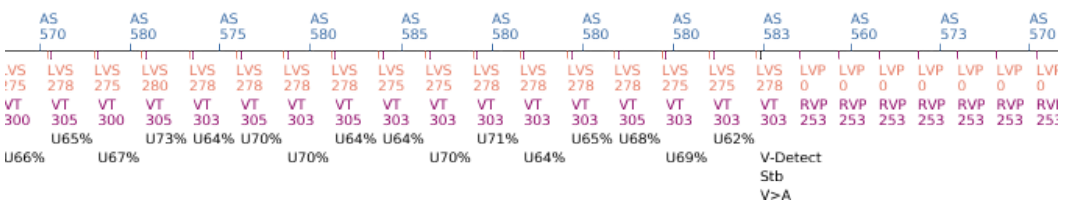
RV
4
5
Shock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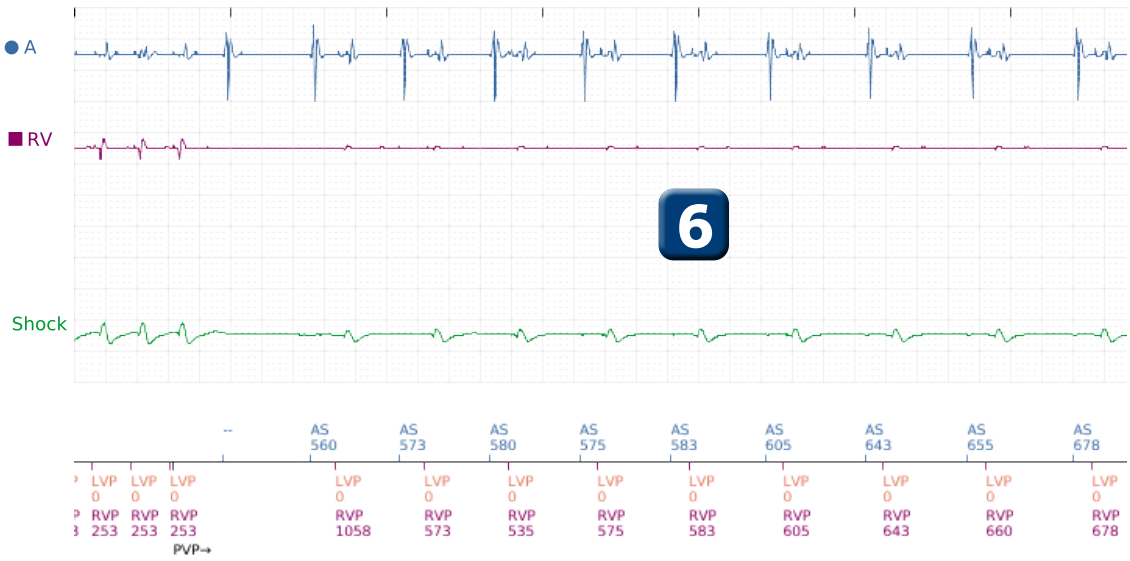
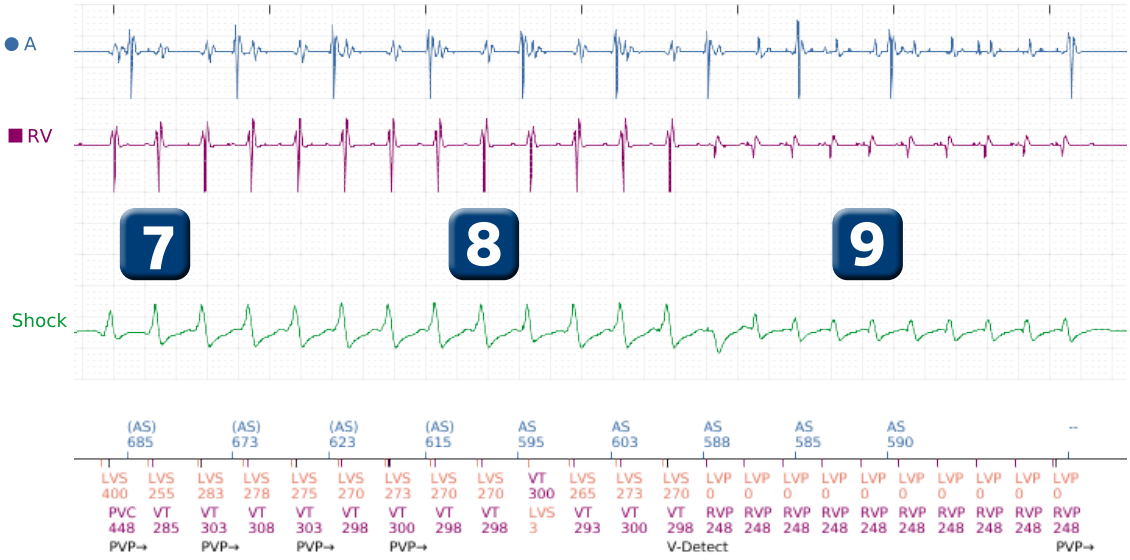
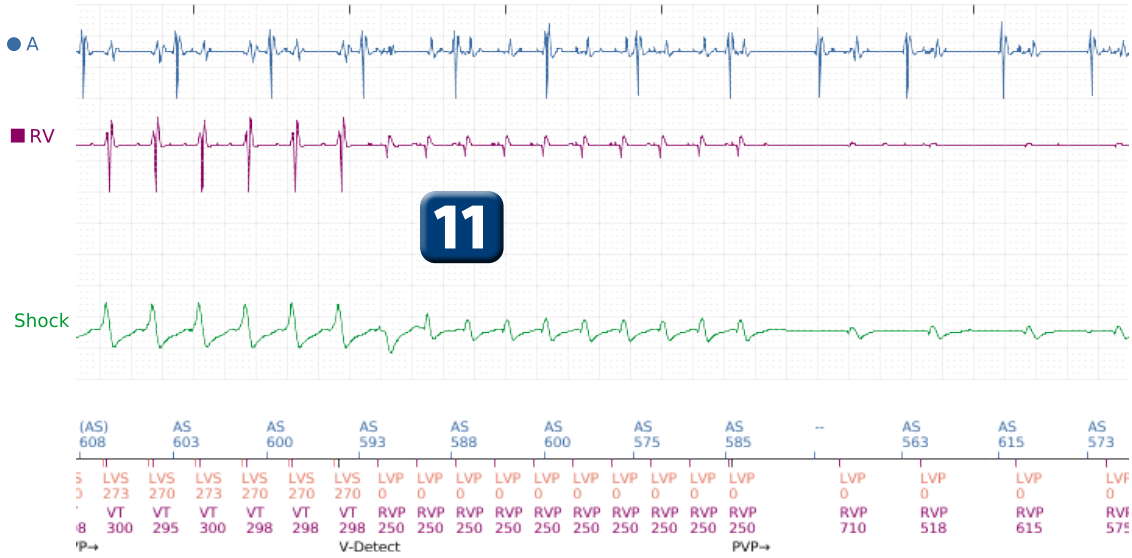
VT 305 VT 300 VT 305 VT 303 VT 305 VT 303 VT 305 VT 303 VT 303 VT 303 VT 303 VT 305 VT 303 VT 303 VT 303 VT 303 RVP 253 RVP 253 RVP 253 RVP 253 RVP 253 RVP 253
U65% U73% U64% U70% U64% U64% U70% U71% U64% U65% U68% U69% U62%
U66% U67% U70% U70% U64% V-Detect Stb V>A


A
RV
6
Shock
-- AS 560 AS 573 AS 580 AS 575 AS 583 AS 605 AS 643 AS 655 AS 678
LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0
RVP 253 RVP 253 RVP 253 RVP 1058 RVP 573 RVP 535 RVP 575 RVP 583 RVP 605 RVP 643 RVP 660 RVP 678
PVP→


A
RV
7
8
9
Shock
(AS) 685 (AS) 673 (AS) 623 (AS) 615 AS 595 AS 603 AS 588 AS 585 AS 590 --
LVS 400 LVS 255 LVS 283 LVS 278 LVS 275 LVS 270 LVS 273 LVS 270 LVS 270 VT 300 LVS 265 LVS 273 LVS 270 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0
PVC 448 VT 285 VT 303 VT 308 VT 303 VT 298 VT 300 VT 298 VT 298 LVS 3 VT 293 VT 300 VT 298 RVP 248 RVP 248 RVP 248 RVP 248 RVP 248 RVP 248 RVP 248 RVP 248 RVP 248 RVP 248
PVP→ PVP→ PVP→ PVP→ V-Detect PVP→


A
RV
10
Shock
AS 558 AS 560 AS 605 AS 593 AS 570 AS 603 AS 580 AS 600 (AS) 593 (AS) 670 (AS) 605
LVP 0 LVP 0 LVS 408 LVP 0 LVS 473 LVP 0 LVP 0 LVP 0 LVS 403 LVS 255 LVS 278 LVS 268 LVS 270 LVS 270
RVP 818 RVP 560 RVS 453 RVP 700 RVS 480 RVP 690 RVP 583 RVP 600 PVC 448 VT 288 VT 310 VT 298 VT 300 VT 298
PVP→ PVP→ PVP→


A
RV
11
Shock
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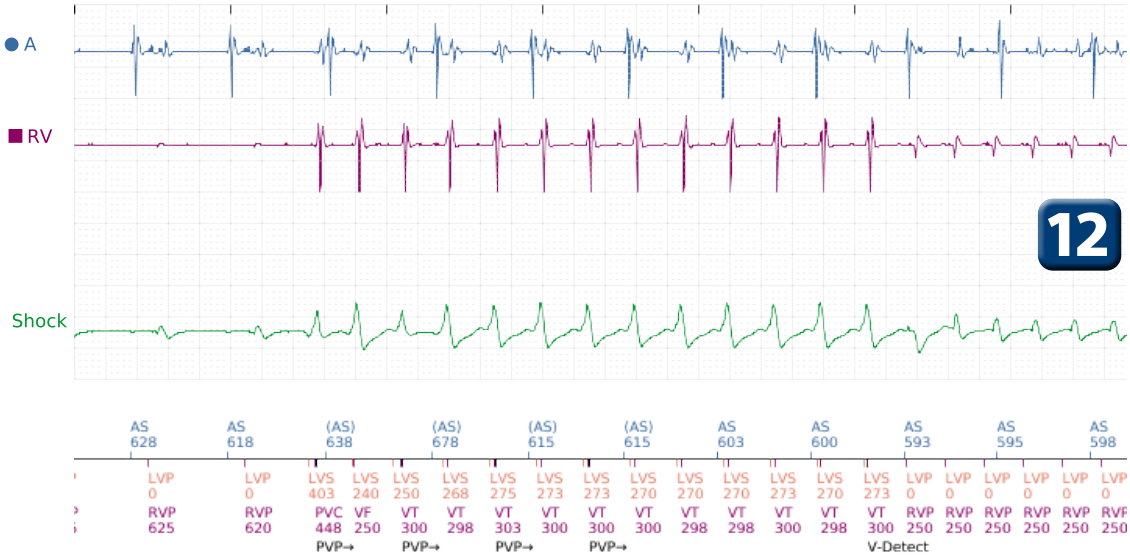
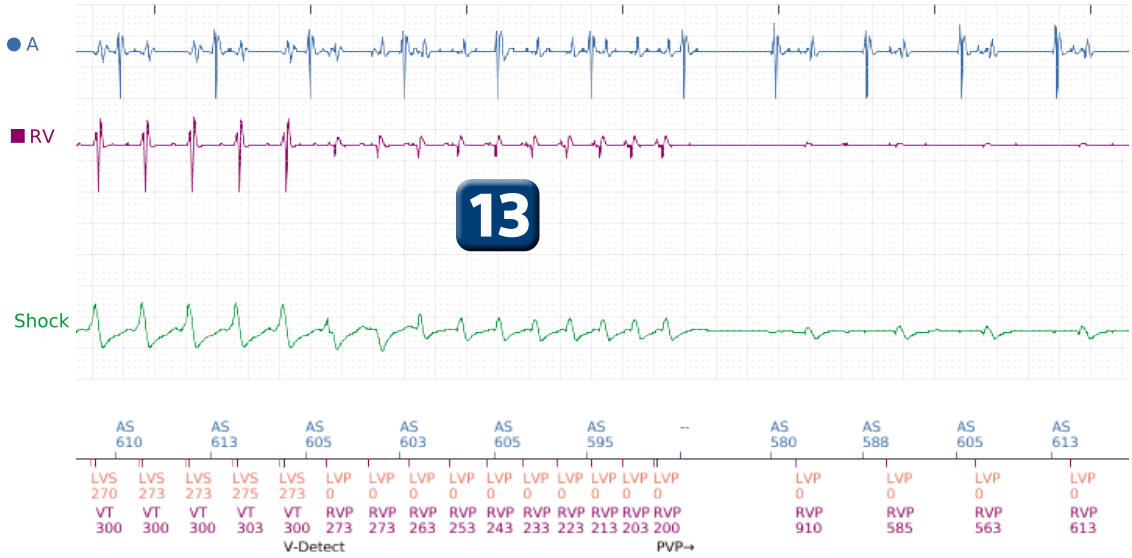
LVS 273 LVS 270 LVS 273 LVS 270 LVS 270 LVS 270 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0
VT 300 VT 295 VT 300 VT 298 VT 298 VT 298 RVP 250 RVP 250 RVP 250 RVP 250 RVP 250 RVP 250 RVP 250 RVP 250 RVP 250 RVP 710 RVP 518 RVP 615
V-Detect PVP→

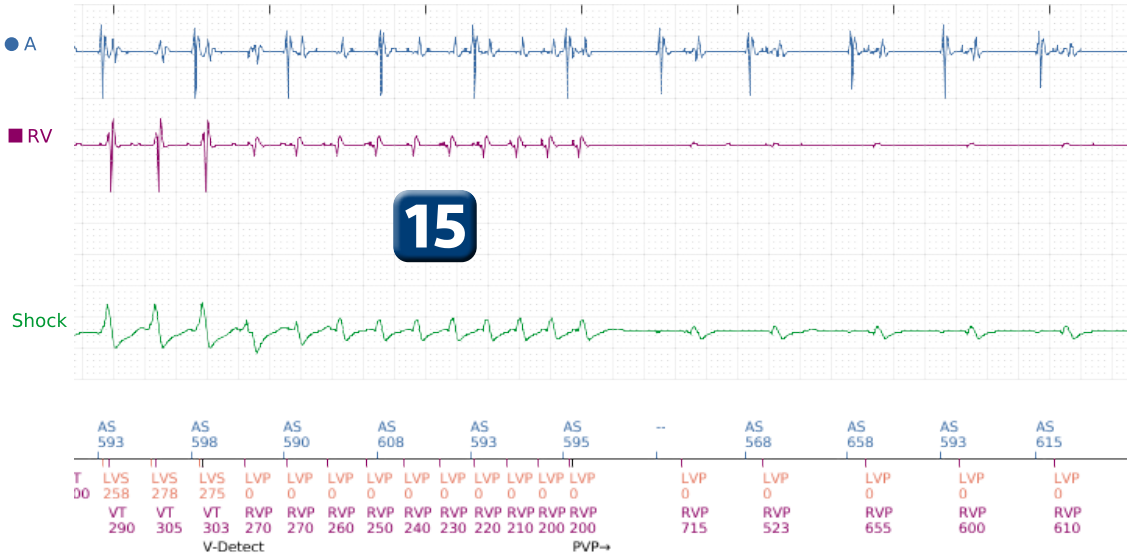

A
RV
12
Shock
AS 628 AS 618 (AS) 638 (AS) 678 (AS) 615 (AS) 615 AS 603 AS 600 AS 593 AS 595 AS 598
LVP 0 RVP 625
LVP 0 RVP 620
LVS 403 LVS 240 PVC 448 250 PVP→
LVS 250 LVS 268 VT 300 298 PVP→
LVS 275 LVS 273 VT 303 300 PVP→
LVS 273 LVS 270 VT 300 300 PVP→
LVS 270 LVS 270 VT 298 298
LVS 273 LVS 270 VT 300 298
LVS 273 VT 300 V-Detect
LVP 0 RVP 250
LVP 0 RVP 250


Attempt 2
A
RV
Shock
-- AS 565 AS 578 AS 603 AS 603 AS 605 (AS) 633 (AS) 633 (AS) 608 (AS) 623
LVP 0 RVP 250 PVP→
LVP 0 RVP 835
LVP 0 RVP 578
LVP 0 RVP 558
LVP 0 RVP 603
LVP 0 RVP 605
LVS 408 LVS 258 PVC 453 VT 285 PVP→
LVS 285 LVS 283 VT 303 VT 313 PVP→
LVS 278 LVS 275 VT 305 VT 303 PVP→
LVS 273 LVS 273 VT 300 VT 303 PVP→

LATITUDE™ Patient Management - Event Detail Report 23 Jan 2023




A
RV
14
Shock
AS 618 AS 603 AS 608 -- AS 575 AS 620 AS 598 (AS) 603 (AS) 595 (AS) 595 (AS) 600
LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0
LVP 0
LVP 0
LVS 425
LVS 280
LVS 288
LVS 288
LVS 278
LVS 278
LVS 275
LVS 275
LVS 275
RVP 273 RVP 263 RVP 253 RVP 243 RVP 233 RVP 223 RVP 213 RVP 203 RVP 200
RVP 1028
RVP 618
RVS 470
VT 290
VT 308
VT 315
VT 305
VT 305
VT 303
VT 305
VT 303
PVP→
PVP→
PVP→
PVP→
PVP→


A
RV
15
Shock
AS 593 AS 598 AS 590 AS 608 AS 593 AS 595 -- AS 568 AS 658 AS 593 AS 615
LVS 258
LVS 278
LVS 275
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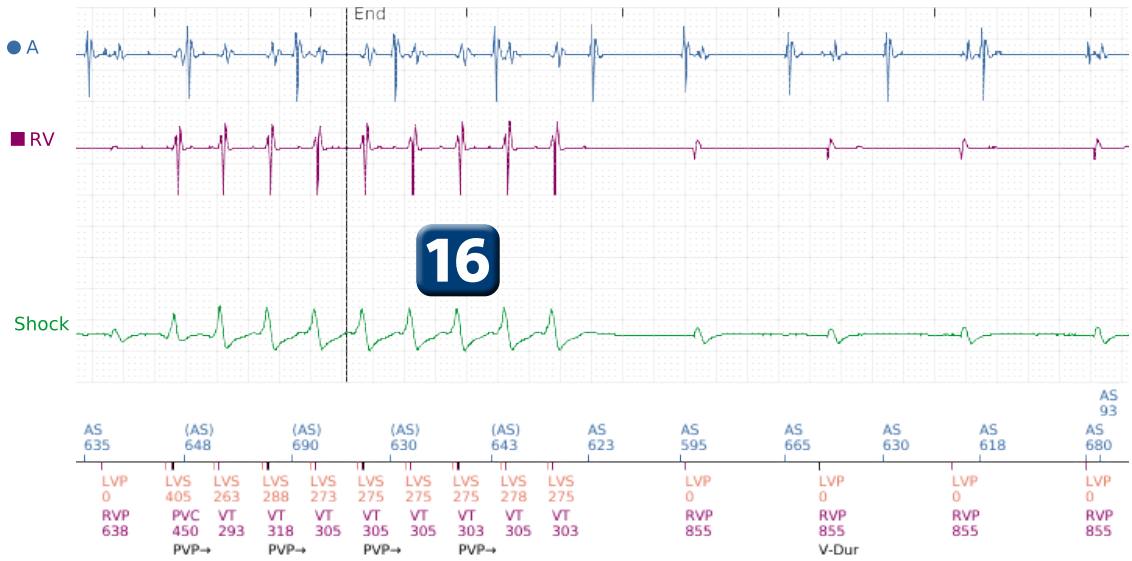
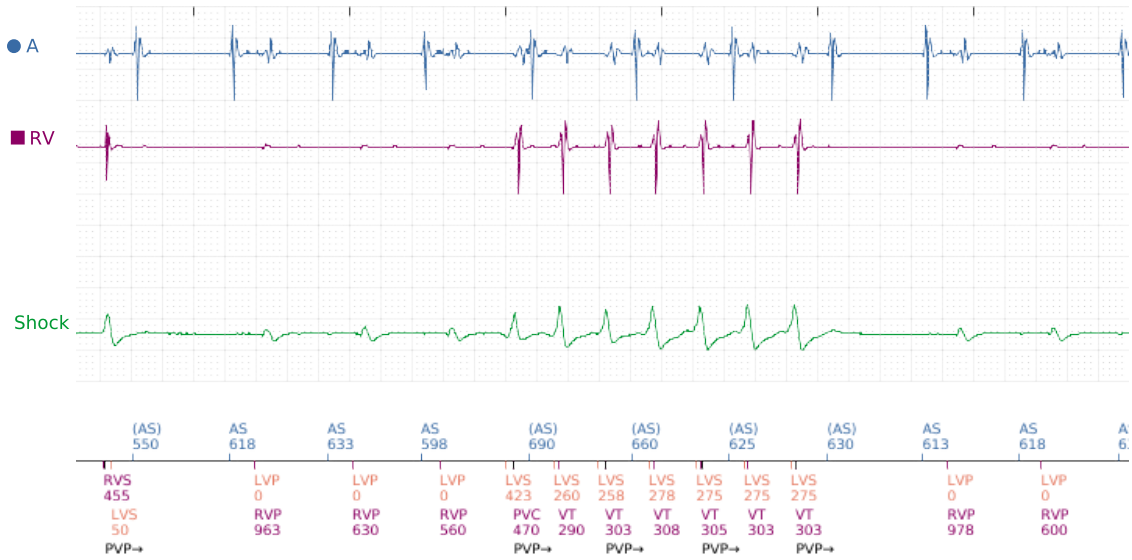
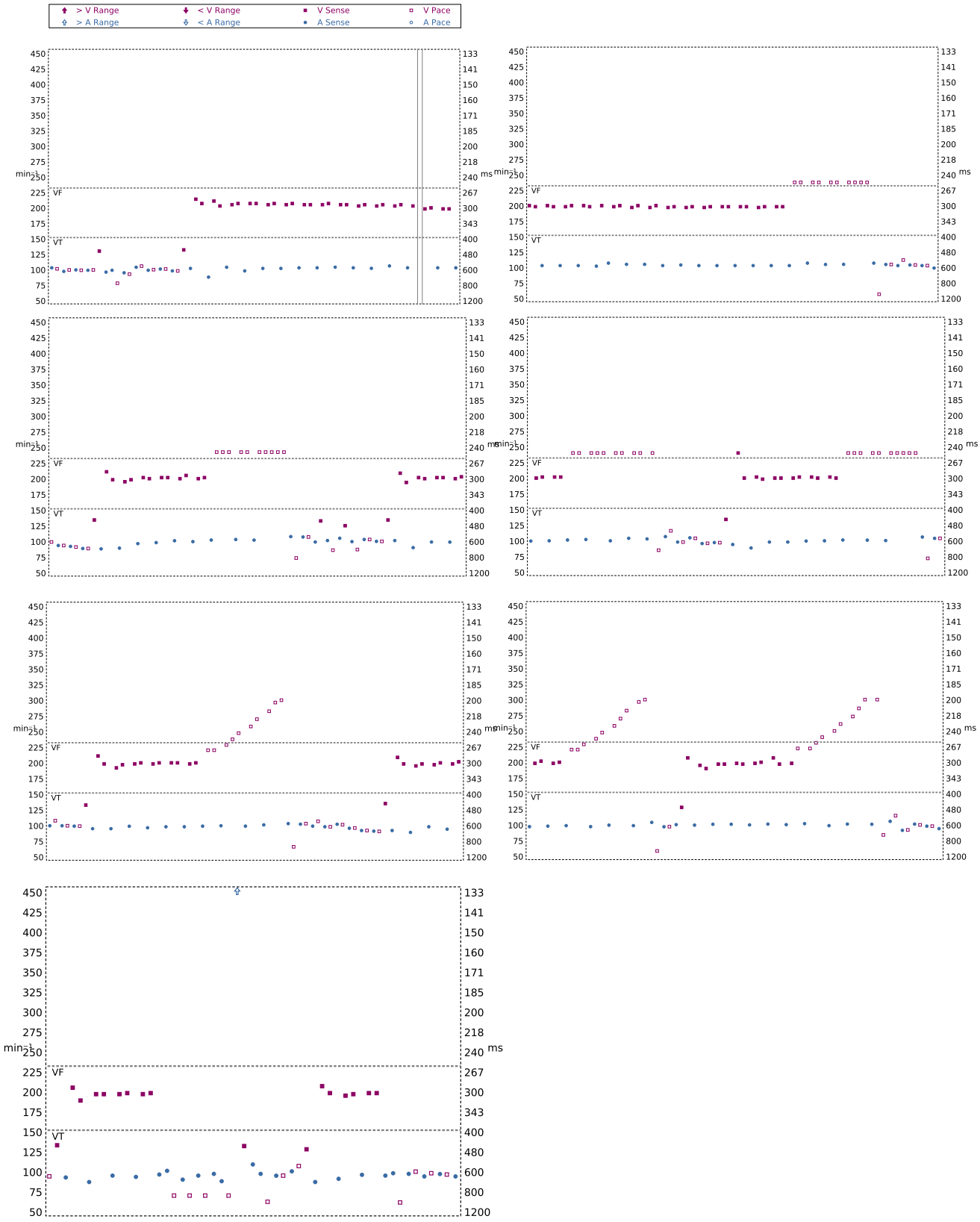
LVP 0
LVP 0
LVP 0
LVP 0
LVP 0
LVP 0
LVP 0
LVP 0
LVP 0
LVP 0
LVP 0
LVP 0
LVP 0
VT 290
VT 305
VT 303
RVP 270
RVP 270
RVP 260
RVP 250
RVP 240
RVP 230
RVP 220
RVP 210
RVP 200
RVP 200
RVP 715
RVP 523
RVP 655
RVP 600
RVP 610
V-Detect
PVP→

LATITUDE™ Patient Management - Event Detail Report 23 Jan 2023

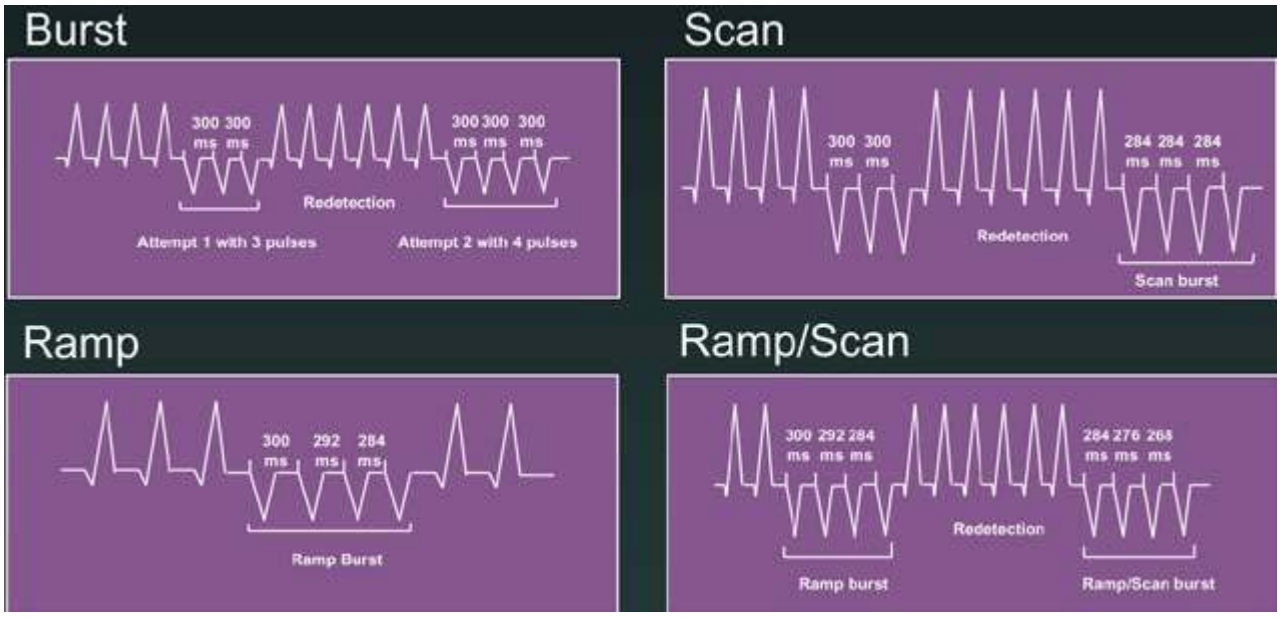





> V Range
< V Range
V Sense
V Pace
> A Range
< A Range
A Sense
A Pace
min-1
ms
VF
VT

Points to remember

- this clinical case highlights the importance of programming the redetection duration time for the VT zone; this patient presented with numerous episodes of VT which terminated spontaneously or following anti-tachycardia pacing; the initial duration was programmed at 12 seconds; anti-tachycardia pacing was effective, but the tachycardia recurred before the end-of-episode marker; the redetection time set at 1 second was then applied, leading to pacing after a limited number of tachycardia cycles
- for an anti-tachycardia pacing sequence, there is no additional delay between the end of the duration and therapy; on the other hand, to deliver a shock, charging time and post-charging confirmation are added; therefore in this patient, it seems advisable to lengthen the redetection duration for the VT zone (which is programmable in the VT zone and not in the VF zone) to encourage possible spontaneous termination of nonsustained VTs



This figure shows the different options for anti-tachycardia pacing:

- burst: interval duration is constant throughout a sequence
- ramp: the interval is reduced from one stimulus to the next by the programmable decrement value
- scan: interval duration is reduced from one burst/ramp to the next

12 Progression of therapies in the VT zone

Patient

- 73-year-old woman implanted with a Resonate CRT defibrillator

Summary

- episode classified in the VT zone
- 4 bursts + 4 ramps + 1 shock of 11 Joules

EGM layout

1 spontaneous atrial rhythm and biventricular pacing

2 monomorphic, regular ventricular tachycardia (atrioventricular dissociation) diagnosed in the VT zone

3 V-Epsd after 8 out of 10 cycles in the VT zone and start of initial VT zone duration (12 seconds)

4 diagnosis of sustained VT (V-Detect) at end of duration (V>A)

5 burst of 10 complexes at fixed rate; biventricular pacing

6 ineffective burst and ongoing arrhythmia

7 criterion 8/10 verified and start of post-detection time (1 second)

8 end of duration, second burst

9 ineffective burst

10 criterion 8/10 verified and start of post-detection time (1 second)

11 third burst

12 fourth burst

13 first ramp

14 second ramp

15 third ramp

16 effective ramp

17 restart of an identical VT before the V-EpsdEnd marker

18 fourth ramp (the device considers this to be the same episode)

19 next therapy is a shock; capacitor charging begins

20 end of charge

21 shock delivered after the end of the diversion window on the second rapid ventricular cycle (2/3 rapid cycle criterion verified)

22 effective shock

V-40: 27 May 2021 14:40, VT, A Rate: 98 min^{-1}, V Rate: 217 min^{-1}

Detail

VT Event Onset	
Avg A Rate	98 min^{-1}
Avg V Rate	217 min^{-1}
Detection	Rhythm ID
Template	04 Apr 2021 12:27
RhythmMatch™ Threshold	94 %

At V-Detect	
Avg A Rate	109 min^{-1}
Avg V Rate	205 min^{-1}
Rate Zone	VT
Stability	3 ms
V>A Rate	True
AFib	False
RhythmID Correlated	False
RhythmMatch™	69 %
SRD Met	(False, Off)
ATP Timeout	False

Attempt 1, Burst V ATP	
Elapsed Time	00:00:30
ATP Information	
Number of Bursts	4

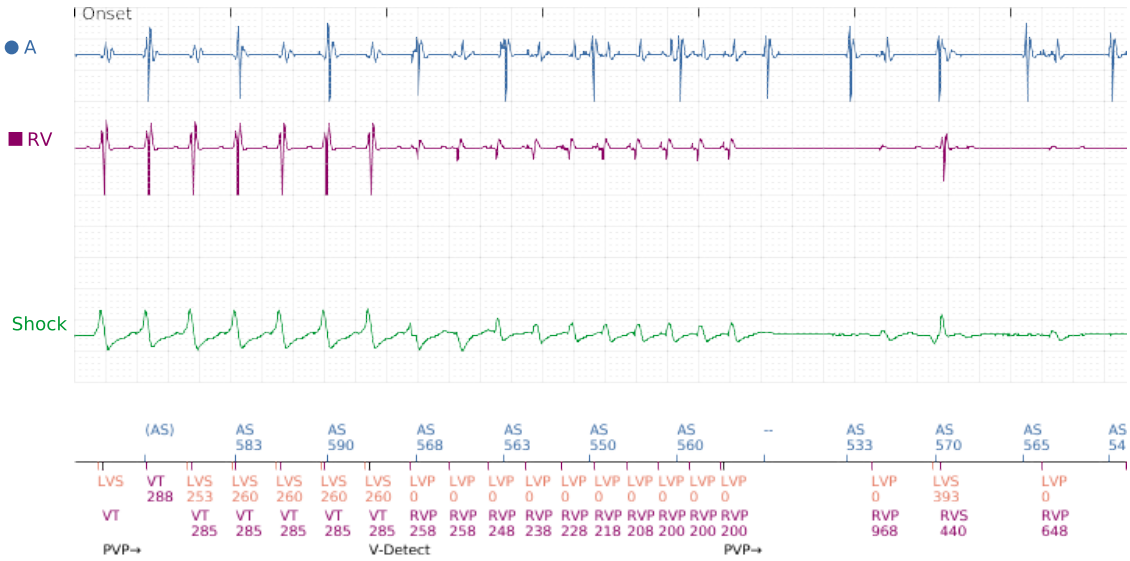
At V-Detect	
Avg A Rate	112 min^{-1}
Avg V Rate	202 min^{-1}
Rate Zone	VT
ATP Timeout	False

Attempt 2, Ramp V ATP	
Elapsed Time	00:00:56
ATP Information	
Number of Bursts	4

At V-Detect	
Avg A Rate	109 min^{-1}
Avg V Rate	233 min^{-1}
Rate Zone	VT
ATP Timeout	False

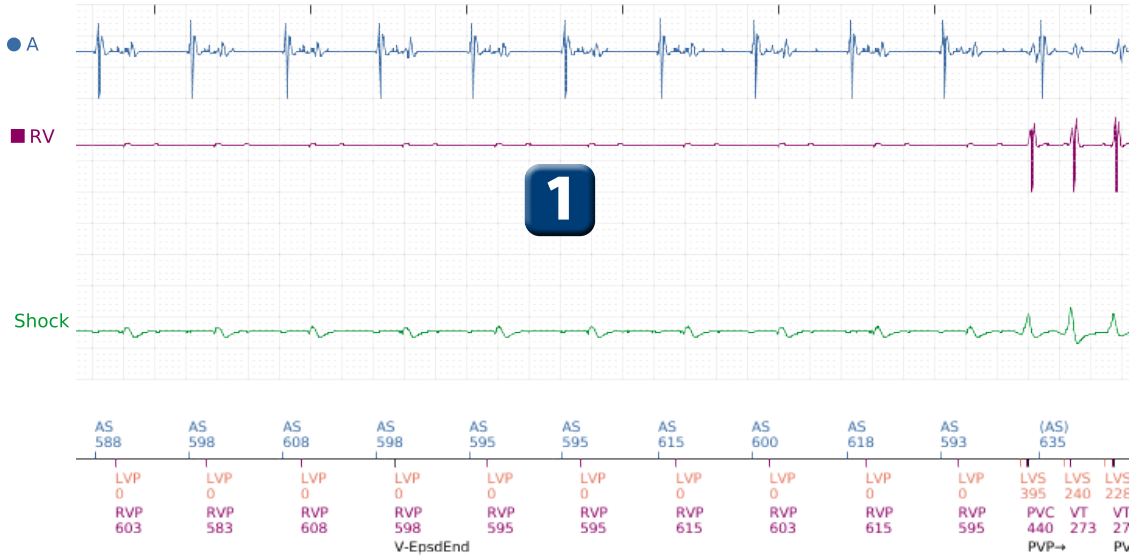
Attempt 3, 11 J V Shock	
Elapsed Time	00:01:28
Shock Information	
Charge Time	2.0 s
Lead Impedance	60 Ω
Lead Polarity	Initial

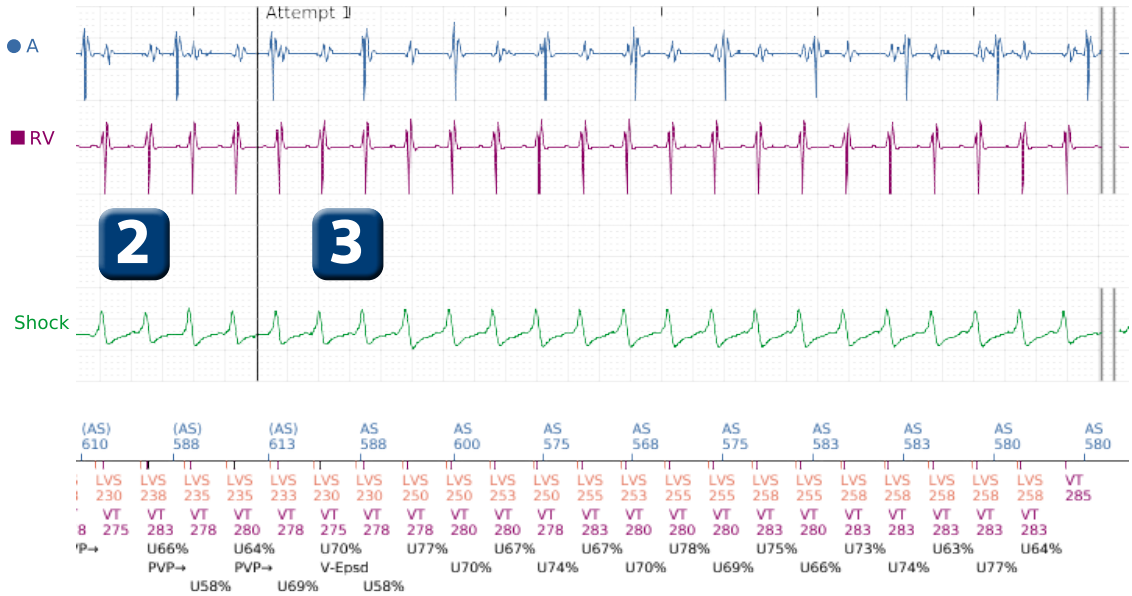
Event Ended	00:02:01

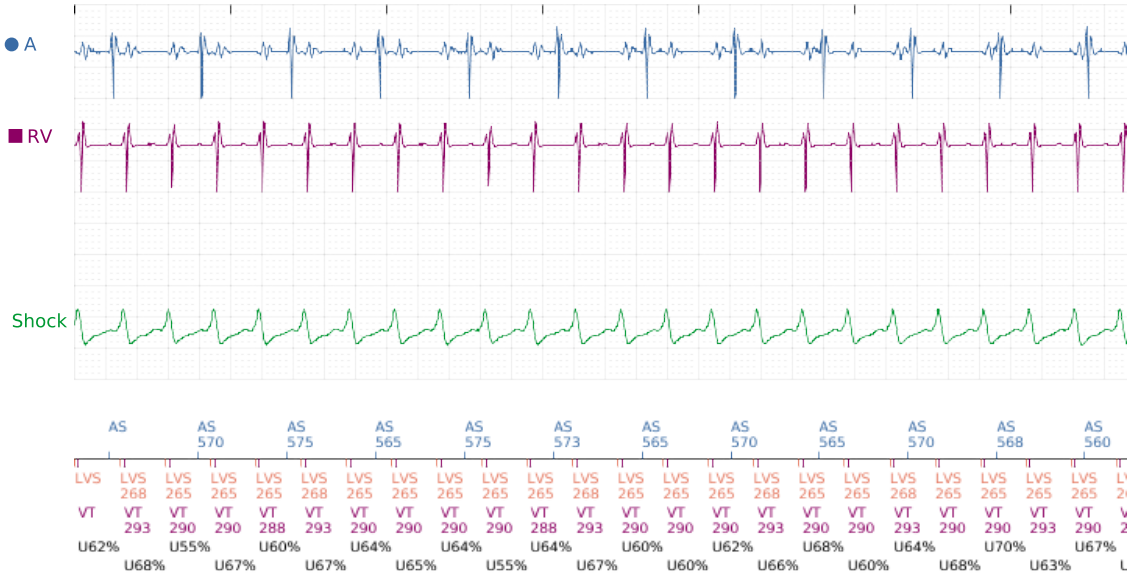

Onset
A
RV
Shock
(AS) AS 583 AS 590 AS 568 AS 563 AS 550 AS 560 -- AS 533 AS 570 AS 565 AS 54
LVS VT 288 LVS 253 LVS 260 LVS 260 LVS 260 LVS 260 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVS 393 LVP 0
VT VT 285 VT 285 VT 285 VT 285 VT 285 RVP 258 RVP 258 RVP 248 RVP 238 RVP 228 RVP 218 RVP 208 RVP 200 RVP 200 RVP 200 RVP 968 RVS 440 RVP 648
PVP→ V-Detect PVP→

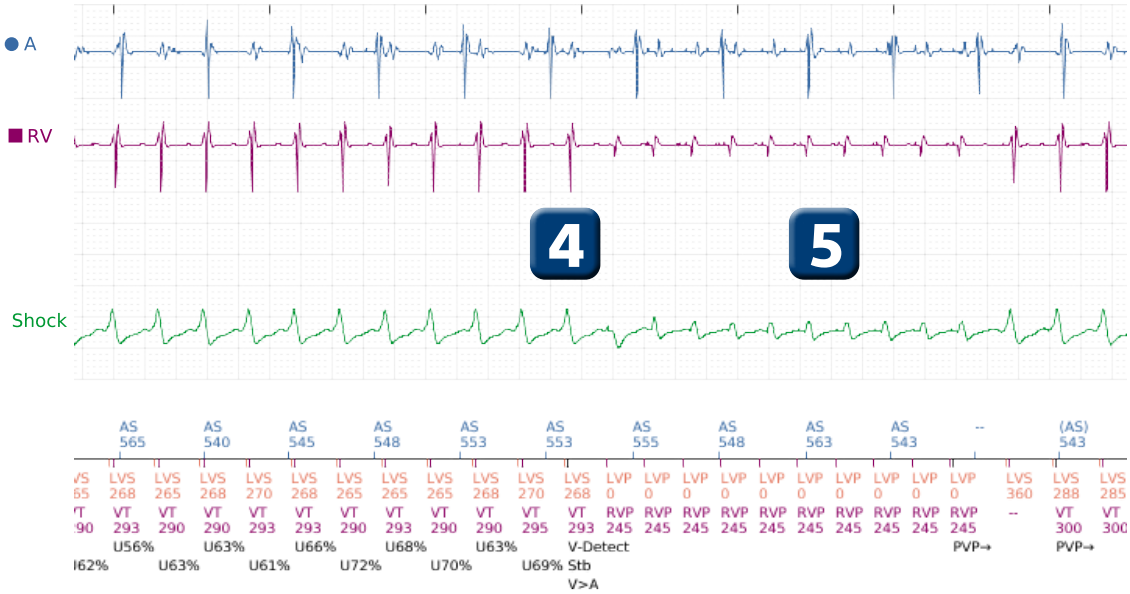

A
RV
Shock
3 AS 540 AS 568 (AS) 563 AS 593 AS 553 AS 578 AS 580 AS 590 AS 600 (AS) 613 AS 630
LVP 0 LVP 0 LVP 0 PVC 420 LVS 3 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVS 425 LVP 0
RVP 545 RVP 538 RVP 568 RVP 735 RVP 565 RVP 565 RVP 583 RVP 590 RVP 600 PVC 448 RVP 795
PVP→ PVP→

LATITUDE™ Patient Management - Event Detail Report 23 Jan 2023






A
RV
Shock
AS AS 570 AS 575 AS 565 AS 575 AS 573 AS 565 AS 570 AS 565 AS 570 AS 568 AS 560
LVS LVS 268 LVS 265 LVS 265 LVS 265 LVS 268 LVS 265 LVS 265 LVS 265 LVS 265 LVS 265 LVS 268 LVS 265 LVS 265 LVS 265 LVS 268 LVS 265 LVS 265 LVS 268 LVS 265 LVS 265 LVS 265 LVS 265
VT VT 293 VT 290 VT 290 VT 288 VT 293 VT 290 VT 290 VT 290 VT 290 VT 288 VT 293 VT 290 VT 290 VT 290 VT 293 VT 290 VT 290 VT 293 VT 290 VT 290 VT 293 VT 290
U62% U55% U60% U64% U64% U64% U60% U62% U68% U64% U70% U67%
U68% U67% U67% U65% U55% U67% U60% U66% U60% U68% U63%


A
RV
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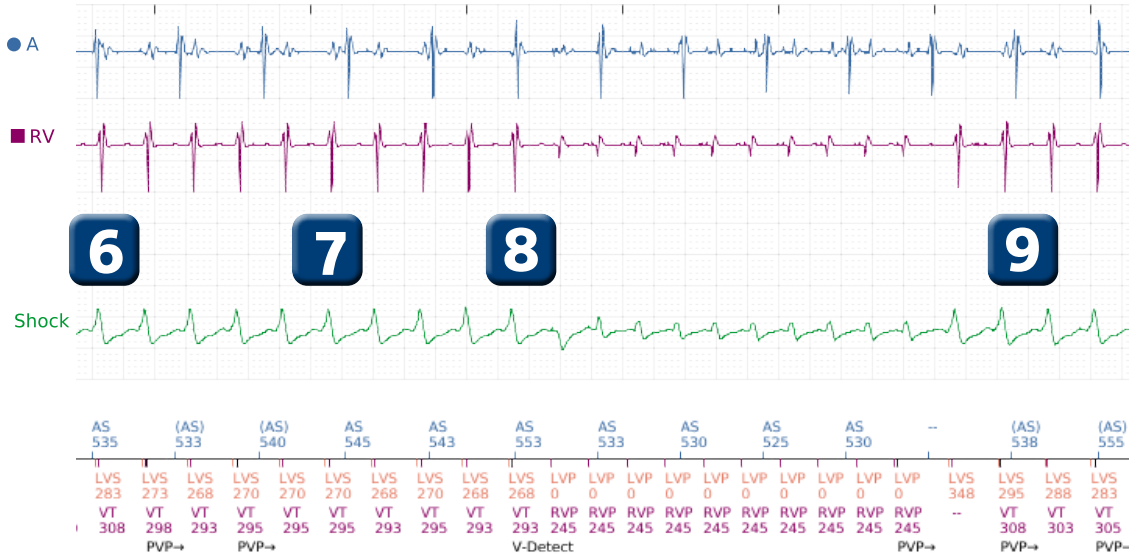
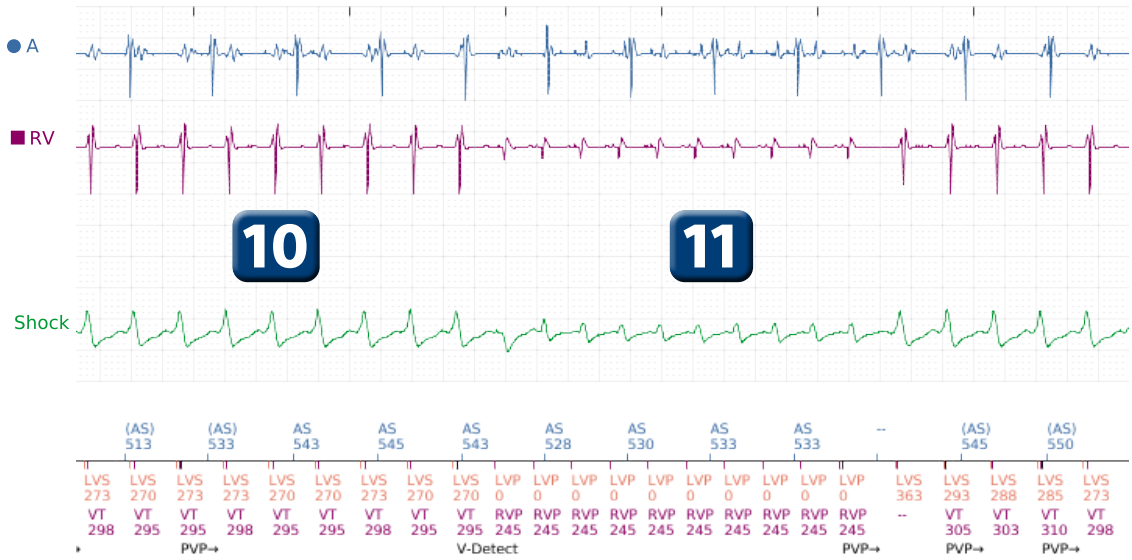
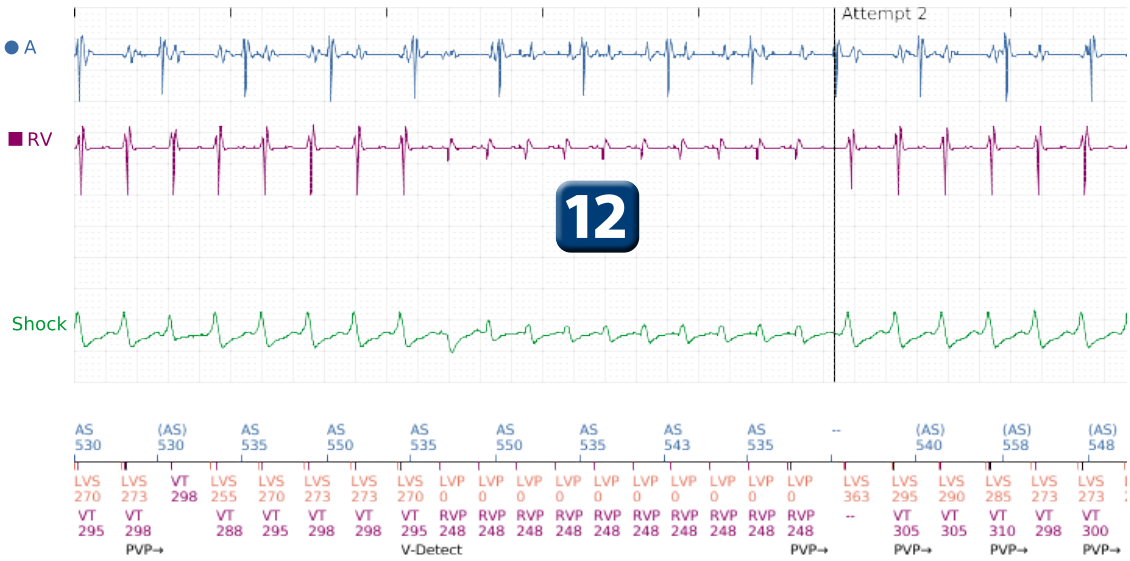
Shock
AS 565 AS 540 AS 545 AS 548 AS 553 AS 553 AS 555 AS 548 AS 563 AS 543 -- (AS) 543
LVS 268 LVS 265 LVS 268 LVS 270 LVS 268 LVS 265 LVS 265 LVS 265 LVS 268 LVS 270 LVS 268 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVS 360 LVS 288 LVS 285
VT 293 VT 290 VT 293 VT 290 VT 293 VT 290 VT 290 VT 295 VT 293 RVP 245 RVP 245 RVP 245 RVP 245 RVP 245 RVP 245 RVP 245 RVP 245 RVP 245 -- VT 300 VT 300
U56% U63% U66% U68% U63% V-Detect PVP→ PVP→
I62% U63% U61% U72% U70% U69% Stb V>A

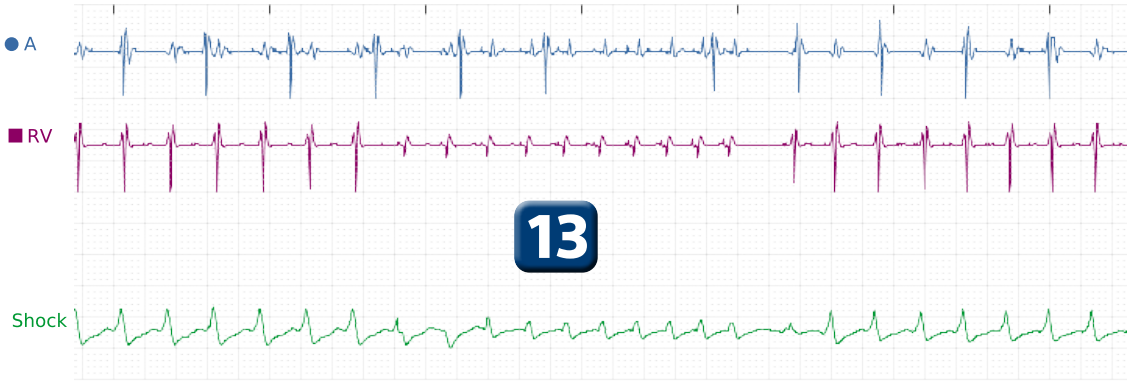
LATITUDE™ Patient Management - Event Detail Report 23 Jan 2023



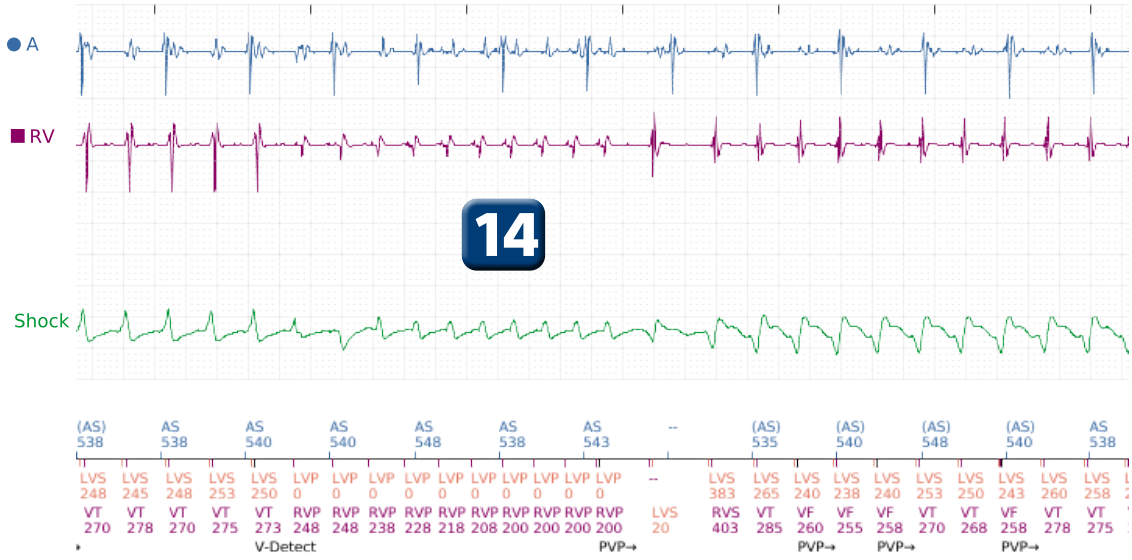




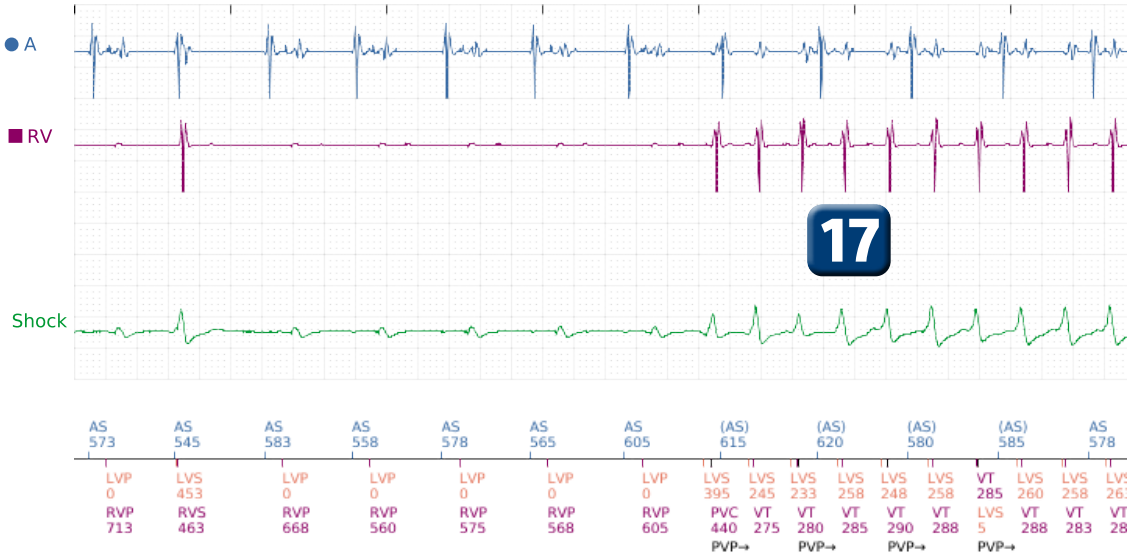
AS 530	(AS) 530		AS 535	AS 550	AS 535	AS 550	AS 535	AS 543	AS 535	--		(AS) 540		(AS) 558		(AS) 548										
LVS 270	LVS 273	VT 298	LVS 255	LVS 270	LVS 273	LVS 273	LVS 270	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVS 363	LVS 295	LVS 290	LVS 285	LVS 273	LVS 273			
VT 295	VT 298		VT 288	VT 295	VT 298	VT 298	VT 295	RVP 248	RVP 248	RVP 248	RVP 248	RVP 248	RVP 248	RVP 248	RVP 248	RVP 248	RVP 248	--	VT 305	VT 305	VT 310	VT 298	VT 300			
	PVP→						V-Detect										PVP→		PVP→		PVP→		PVP→			

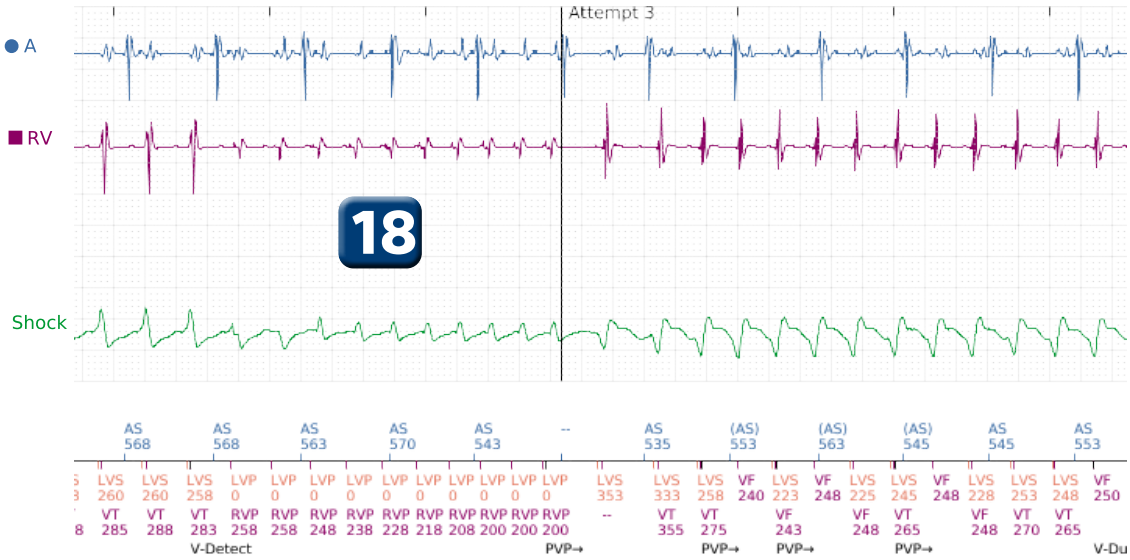


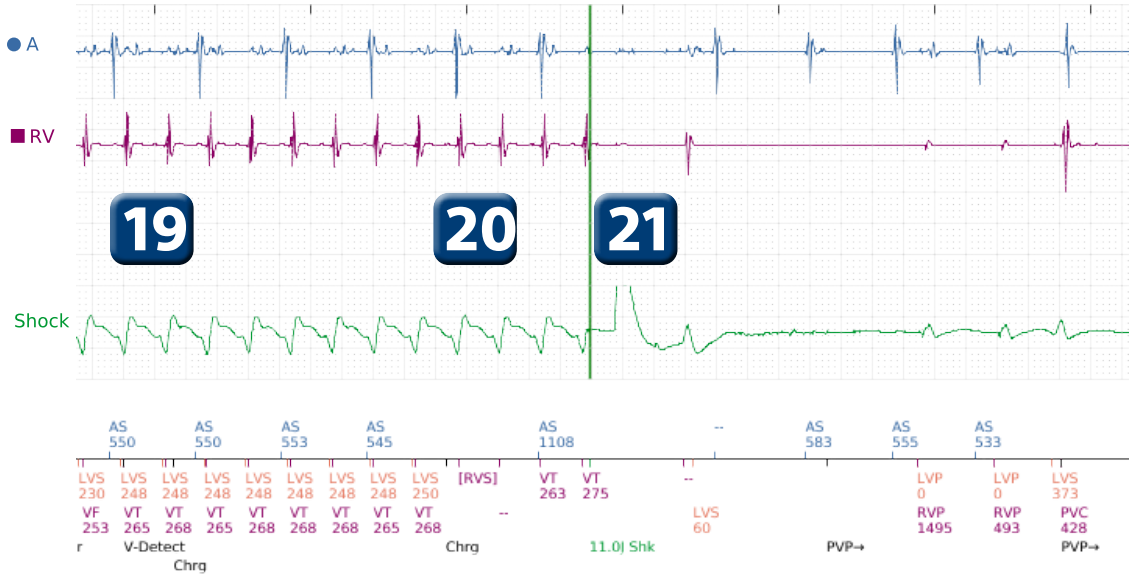
AS 538		AS 533		AS 538	AS 550		AS 548		AS 540							AS 1080		--		(AS) 533		AS 540		(AS) 530		
LVS 270	LVS 270	LVS 273	LVS 273	LVS 275	LVS 273	LVS 270	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVP 0	LVS 410	LVS 253	LVS 273	LVS 285	LVS 248	LVS 255	LVS 248	LVS 255	
VT 298	VT 295	VT 298	VT 295	VT 298	VT 300	VT 295	RVP 270	RVP 270	RVP 260	RVP 250	RVP 240	RVP 230	RVP 220	RVP 210	RVP 200	RVP 200	--	VF 258	VT 285	VT 308	VT 270	VT 278	VT 270	VT 278		
						V-Detect										PVP→			PVP→			PVP→		PVP→			

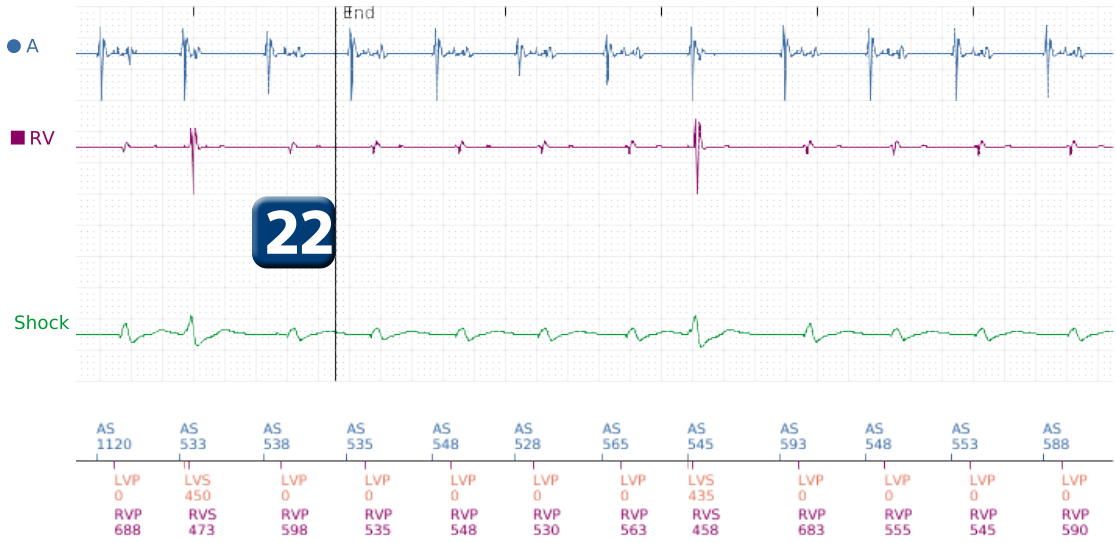

A
RV
14
Shock
(AS) 538 AS 538 AS 540 AS 540 AS 548 AS 538 AS 543 -- (AS) 535 (AS) 540 (AS) 548 (AS) 540 AS 538
LVS 248 LVS 245 LVS 248 LVS 253 LVS 250 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 -- LVS 383 LVS 265 LVS 240 LVS 238 LVS 240 LVS 253 LVS 250 LVS 243 LVS 260 LVS 258
VT 270 VT 278 VT 270 VT 275 VT 273 RVP 248 RVP 248 RVP 238 RVP 228 RVP 218 RVP 208 RVP 200 RVP 200 RVP 200 RVP 200 LVS 20 RVS 403 VT 285 VF 260 VF 255 VF 258 VT 270 VT 268 VF 258 VT 278 VT 275
V-Detect
PVP→
PVP→
PVP→
PVP→

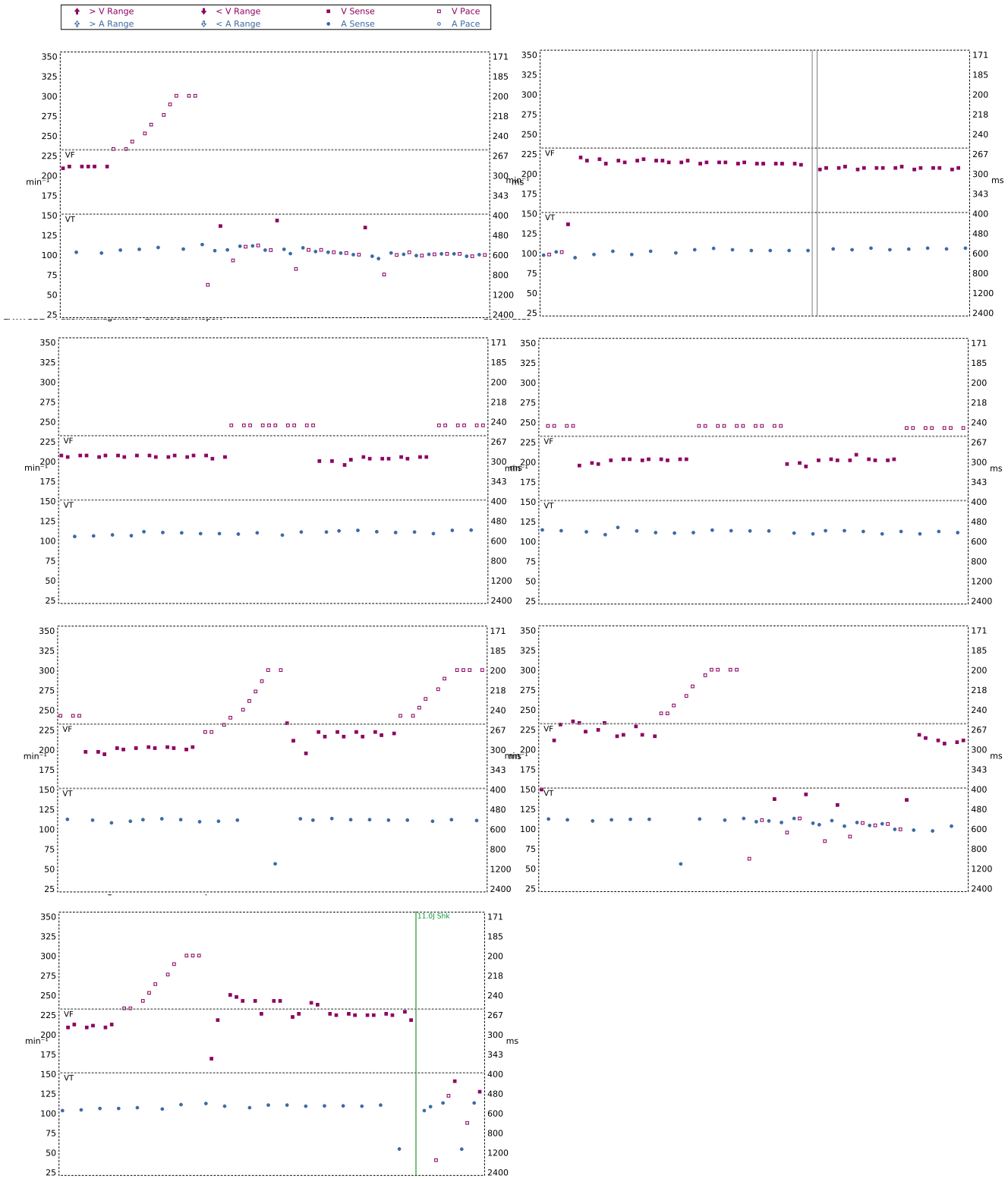

A
RV
15
16
Shock
AS 538 AS 1083 AS 535 AS 543 -- AS 533 AS 553 AS 548 AS 558 AS 533 (AS) 563
LVS 258 LVS 260 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVS 393 LVP 0 LVP 0 LVS 363
VT 275 VT 278 RVP 245 RVP 245 RVP 235 RVP 225 RVP 215 RVP 205 RVP 200 RVP 200 RVP 200 RVP 200 RVP 965 RVP 543 RVS 438 RVP 630 RVP 533 PVC 420
V-Detect
PVP→
PVP→


A
RV
17
Shock
AS 573 AS 545 AS 583 AS 558 AS 578 AS 565 AS 605 (AS) 615 (AS) 620 (AS) 580 (AS) 585 AS 578
LVP 0 LVS 453 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVS 395 LVS 245 LVS 233 LVS 258 LVS 248 LVS 258 VT 285 LVS 260 LVS 258
RVP 713 RVS 463 RVP 668 RVP 560 RVP 575 RVP 568 RVP 605 PVC 440 VT 275 VT 280 VT 285 VT 290 VT 288 LVS 5 VT 288 VT 283
PVP→ PVP→ PVP→ PVP→


Attempt 3
A
RV
18
Shock
AS 568 AS 568 AS 563 AS 570 AS 543 -- AS 535 (AS) 553 (AS) 563 (AS) 545 AS 545 AS 553
LVS 260 LVS 260 LVS 258 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVS 353 LVS 333 LVS 258 VF 240 LVS 223 VF 248 LVS 225 LVS 245 VF 248 LVS 228 LVS 253 LVS 248 VF 250
VT 285 VT 288 VT 283 RVP 258 RVP 258 RVP 248 RVP 238 RVP 228 RVP 218 RVP 208 RVP 200 RVP 200 RVP 200 -- VT 355 VT 275 VF 243 VF 248 VT 265 VF 248 VT 270 VT 265
V-Detect PVP→ PVP→ PVP→ PVP→ PVP→ V-Du


A
RV
19
20
21
Shock
AS 550 AS 550 AS 553 AS 545 AS 1108 -- AS 583 AS 555 AS 533
LVS 230 LVS 248 LVS 248 LVS 248 LVS 248 LVS 248 LVS 248 LVS 248 LVS 250 [RVS] VT 263 VT 275 -- LVP 0 LVP 0 LVS 373
VF 253 VT 265 VT 268 VT 265 VT 268 VT 268 VT 268 VT 265 VT 268 -- LVS 60 RVP 1495 RVP 493 PVC 428
r V-Detect Chrg Chrg 11.0J Shk PVP→ PVP→


End
A
RV
22
Shock
AS 1120 AS 533 AS 538 AS 535 AS 548 AS 528 AS 565 AS 545 AS 593 AS 548 AS 553 AS 588
LVP 0 LVS 450 LVP 0 LVP 0 LVP 0 LVP 0 LVP 0 LVS 435 LVP 0 LVP 0 LVP 0 LVP 0
RVP 688 RVS 473 RVP 598 RVP 535 RVP 548 RVP 530 RVP 563 RVS 458 RVP 683 RVP 555 RVP 545 RVP 590


> V Range
< V Range
V Sense
V Pace
> A Range
< A Range
A Sense
A Pace
VF
VT
min-1
ms
11.0J Shk

Points to remember

- during this episode, the first sequences of anti-tachycardia pacing fail to terminate the arrhythmia; as in the previous trace, anti-tachycardia pacing is then effective, but the tachycardia recurs before the end-of-episode marker, and successive therapies follow until a shock is delivered ; the programming of ramps following bursts is not systematic for this rate range since it is more aggressive with an increased risk of acceleration into a rapid polymorphic tachycardia

to optimize the effectiveness of anti-tachycardia pacing, various parameters can be programmed:

1 type of sequence : in a burst, the interval duration is constant during a sequence (no change in frequency from one stimulus to the next); in a ramp, the interval is reduced from one stimulus to the next by the value of the programmable decrement;

2 the number of bursts/ramps programmed varies according to the rate of the tachycardia; it is possible to program 2 burst or ramp sequences per VT or VT-1 zone; in a slow VT zone (< 150 beats/minute), it is possible to program a large number of bursts and/or ramps, to delay as long as possible shock delivery to a tachycardia that does not generally threaten short-term survival; for tachycardias between 150 and 200 beats/minute, it is usual to program 2 to 6 bursts/ramps, even if the success rate beyond 3 or 4 bursts is very limited;

3 the number of pulses per sequence: on average, 5 to 15 consecutive pacing impulses are programmed in each burst; if the number is too low, the stimulation sequence may not penetrate the tachycardia circuit and the burst is ineffective; on the other hand, if the number is too high, there is a risk of terminating and then re-inducing the tachycardia; an additional stimulus can be added systematically from one sequence to the next; according to the guidelines, a minimum number of 8 stimuli per sequence should be programmed;

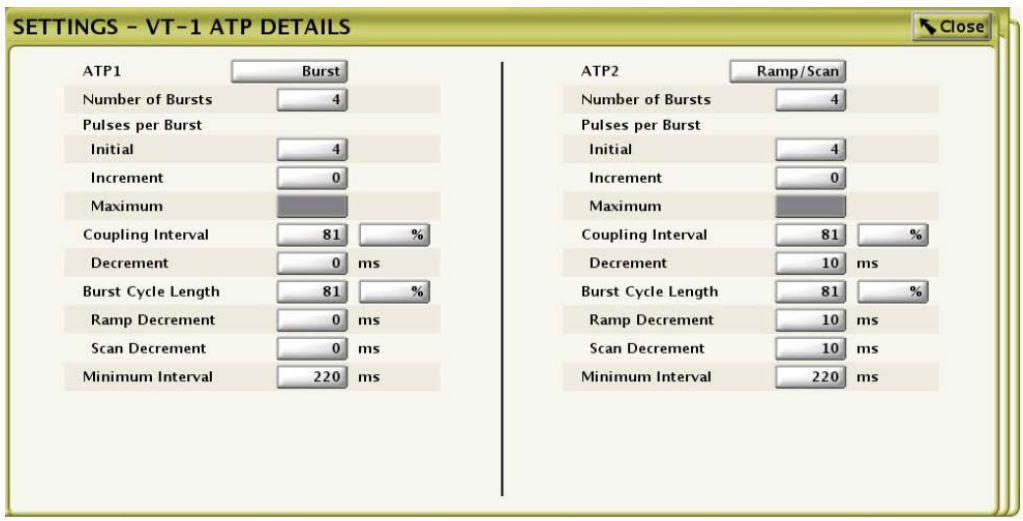
4 the value of coupling and pacing intervals: the shorter the coupling, the more aggressive the therapy and the greater the risk of accelerating the tachycardia; according to the guidelines,

for a burst, a coupling of 88% in relation to the rate of the tachycardia should be programmed; for Boston Scientific defibrillators, the coupling interval (interval between the last tachycardia cycle and the first pacing cycle) and the pacing interval (interval between different paced impulses) are independently programmable; the percentage is calculated in relation to the average of the 4 intervals preceding therapy;

5 minimum coupling limits the aggressiveness of a stimulation sequence; there is a programmable rate limit above which, regardless of programming, the device will not deliver stimulation; when, during a ramp for example, the minimum coupling interval is reached, subsequent cycles are paced with this minimum coupling interval without further decrementing;

6 stimulation amplitude and pulse duration can be programmed to favor effective capture during tachycardia (5 Volts/1 ms);

7 maximum duration for ATP : this defines the time after which ATP sequences will be interrupted to deliver a shock; the idea is not to delay the onset of the first shock by too many ATP sequences.



This figure shows the various programming options for optimizing the effectiveness of the anti-tachycardia pacing sequence(s).

13 Low-amplitude shock and acceleration of arrhythmia

Patient

- 80-year-old male implanted with an Incepta CRT defibrillator

Summary

- episode classified in the VT zone
- 4 bursts + 3 ramps + 1 shock of 11 Joules + 1 shock of 41 Joules

EGM layout

1 regular monomorphic ventricular tachycardia (atrioventricular dissociation) diagnosed in the VT zone

2 burst of 8 complexes at fixed rate; biventricular pacing

3 ineffective burst and ongoing arrhythmia

4 second burst with additional paced impulse

5 third burst

6 fourth burst

7 first ramp

8 second ramp

9 third ramp

10 next therapy is a shock; capacitor charging begins

11 11 Joule shock delivered after the end of the diversion window on the second rapid ventricular cycle (2/3 rapid cycle criterion verified)

12 accelerated ventricular rate with very fast VT detected in the VF zone

13 VF episode detection and capacitor charging

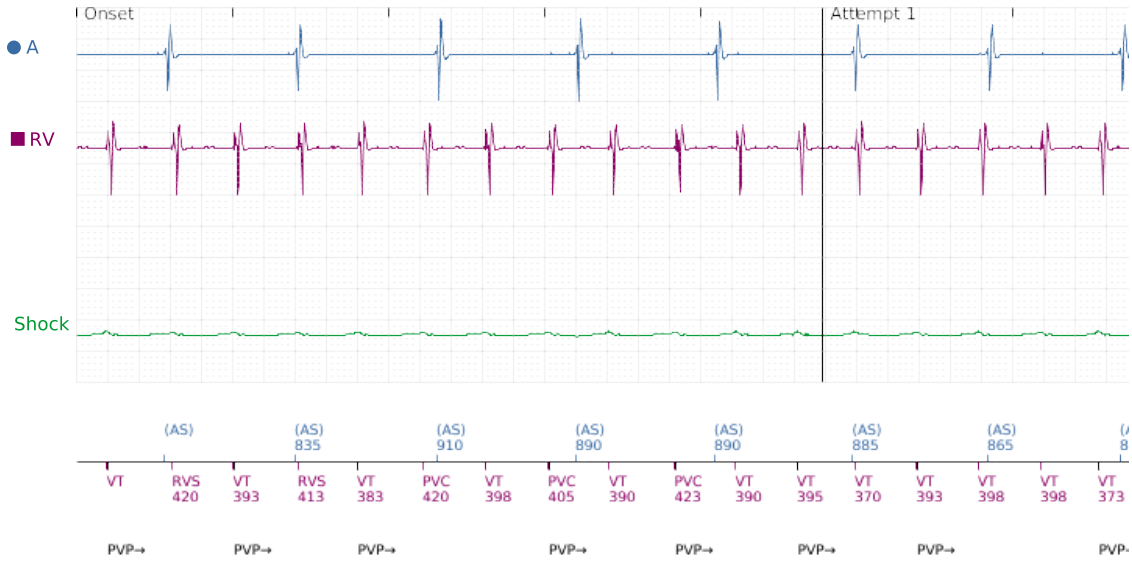
14 41 Joule effective shock

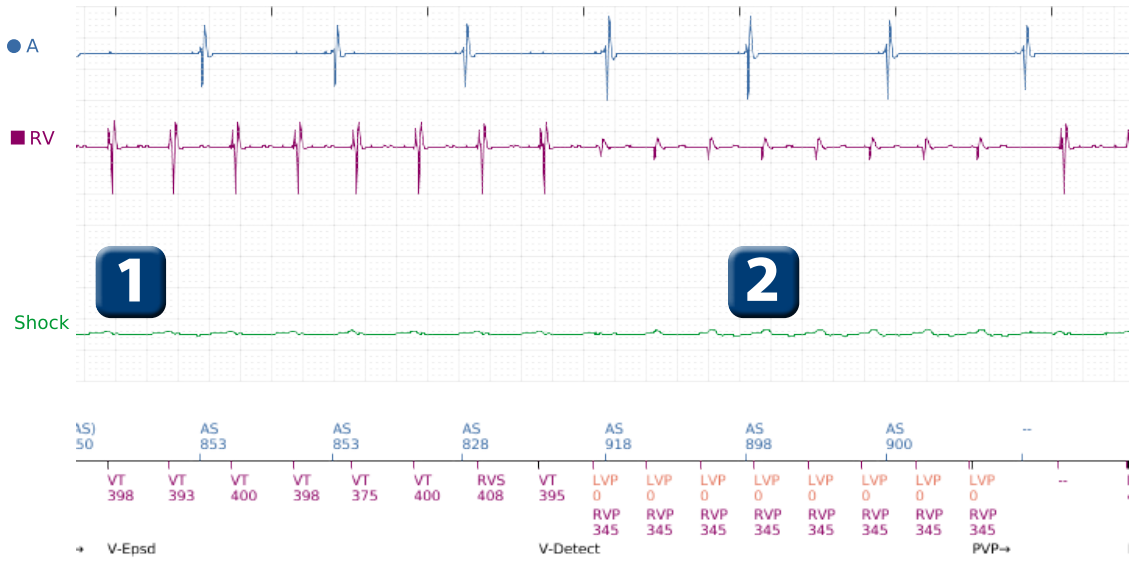
V-832: 05 Feb 2018 09:31, VT, A Rate: 69 min^{-1}, V Rate: 153 min^{-1}

Detail

VT Event Onset	
Avg A Rate	69 min^{-1}
Avg V Rate	153 min^{-1}
Detection	Rate Only
Template	N/R
At V-Detect	
Avg A Rate	71 min^{-1}
Avg V Rate	152 min^{-1}
Rate Zone	VT
Stability	(13 ms, Off)
V>A Rate	(True, Off)
AFib	(False, Off)
RhythmMatch™	N/R
SRD Met	(False, Off)
ATP Timeout	False
Onset Intvl	(8 ms, Off)
Onset %	(1 %, Off)
At V-Detect	
Avg A Rate	66 min^{-1}
Avg V Rate	154 min^{-1}
Rate Zone	VT
ATP Timeout	False
At V-Detect	
Avg A Rate	66 min^{-1}
Avg V Rate	156 min^{-1}
Rate Zone	VT
ATP Timeout	False
At V-Detect	
Avg A Rate	N/R
Avg V Rate	274 min^{-1}
Rate Zone	VF
Stability	(5 ms, Off)
V>A Rate	(True, Off)
AFib	(False, Off)
SRD Met	(False, Off)
ATP Timeout	False
Event Ended	

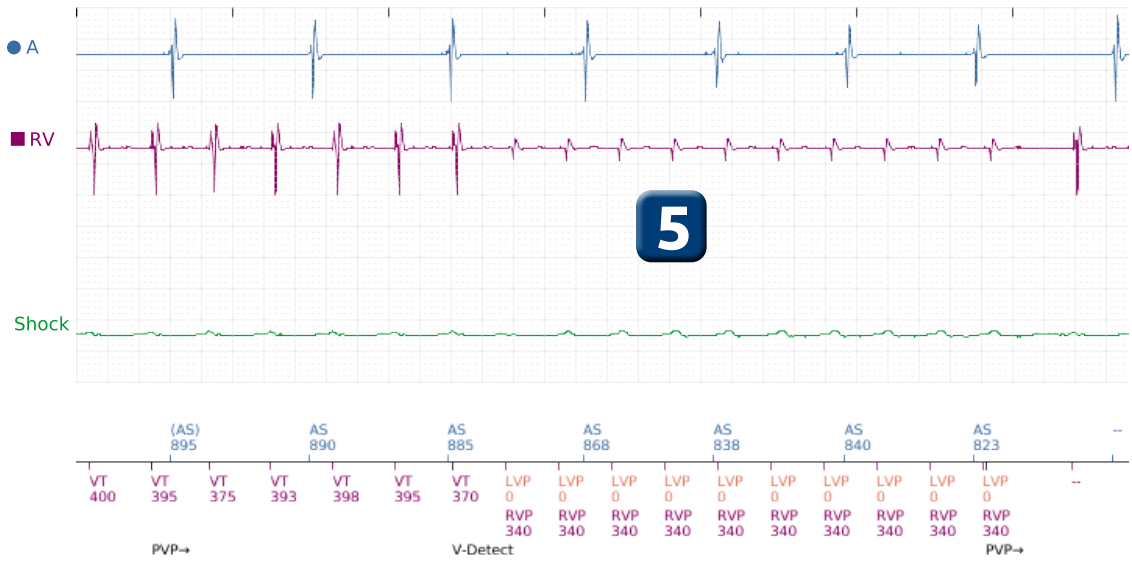
Attempt 1, Burst V ATP	
Elapsed Time	00:00:04
ATP Information	
Number of Bursts	4
Attempt 2, Ramp V ATP	
Elapsed Time	00:00:45
ATP Information	
Number of Bursts	3
Attempt 3, 11 J V Shock	
Elapsed Time	00:01:19
Shock Information	
Charge Time	2.3 s
Lead Impedance	35 Ω
Lead Polarity	Initial
Attempt 4, 41 J V Shock	
Elapsed Time	00:01:26
Shock Information	
Charge Time	11.2 s
Lead Impedance	37 Ω
Lead Polarity	Initial
	00:02:10


Onset
Attempt 1
A
RV
Shock
(AS) (AS) 835 (AS) 910 (AS) 890 (AS) 890 (AS) 885 (AS) 865
VT VT RVS 420 VT 393 RVS 413 VT 383 PVC 420 VT 398 PVC 405 VT 390 PVC 423 VT 390 VT 395 VT 370 VT 393 VT 398 VT 398 VT 373
PVP→ PVP→ PVP→ PVP→ PVP→ PVP→ PVP→ PVP→

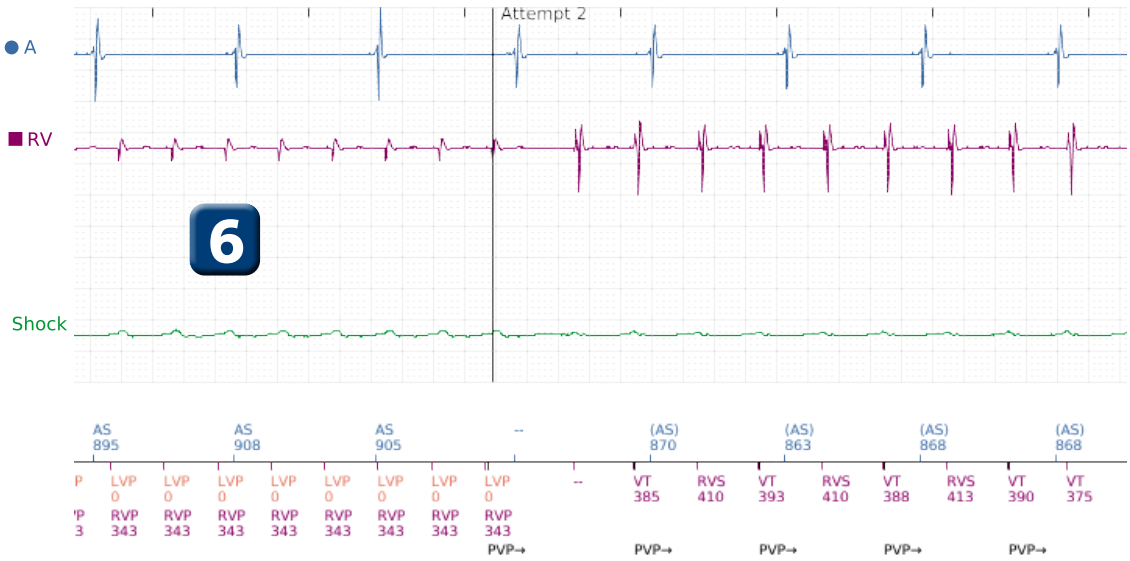

A
RV
Shock
1
2
AS 853 AS 853 AS 828 AS 918 AS 898 AS 900
VT 398 VT 393 VT 400 VT 398 VT 375 VT 400 RVS 408 VT 395
LVP 0 RVP 345
V-Epsd
V-Detect
PVP→

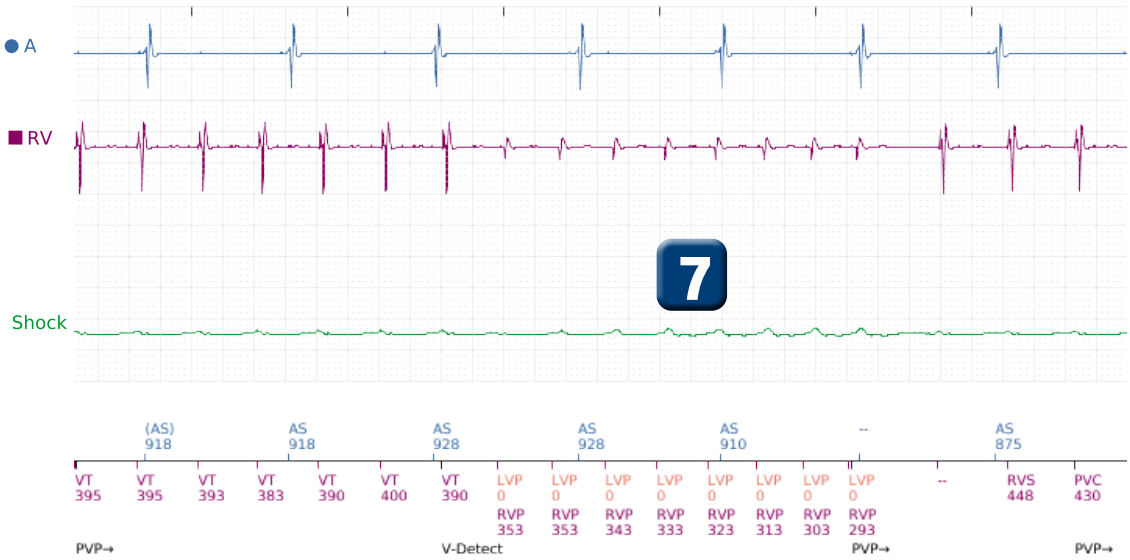

A
RV
3
Shock
(AS) 860
(AS) 848
(AS) 840
(AS) 913
(AS) 910
(AS) 890
AS 873
AS 845
PVC 440
RVS 420
PVC 428
VT 398
PVC 425
VT 393
VT 395
VT 393
VT 370
VT 398
VT 398
PVC 403
VT 368
VT 393
VT 400
VT 398
LVP 0
RVP 340
PVP→
V-Detect


A
RV
4
Shock
AS 838
AS 913
AS 890
(AS) 870
(AS) 850
(AS) 828
(AS) 843
LVP 0
RVP 340
RVS 403
VT 320
RVS 488
PVC 430
VT 370
PVC 410
VT 395
VT 375
VT 398
PVP→


A
RV
5
Shock
(AS) 895
AS 890
AS 885
AS 868
AS 838
AS 840
AS 823
VT 400
VT 395
VT 375
VT 393
VT 398
VT 395
VT 370
LVP 0
RVP 340
PVP→
V-Detect
PVP→


A
RV
Shock
(AS) 908
(AS) 888
(AS) 860
(AS) 843
(AS) 848
AS 838
AS 898
RVS 435
VT 373
RVS 403
VT 400
PVC 410
VT 375
PVC 413
VT 395
VT 388
VT 398
VT 398
VT 380
VT 400
VT 393
VT 395
VT 373
LVP 0
RVP 343
PVP→
V-Detect


Attempt 2
A
RV
6
Shock
AS 895
AS 908
AS 905
--
(AS) 870
(AS) 863
(AS) 868
(AS) 868
P LVP 0 RVP 343
LVP 0 RVP 343
LVP 0 RVP 343
LVP 0 RVP 343
LVP 0 RVP 343
LVP 0 RVP 343
LVP 0 RVP 343
LVP 0 RVP 343
LVP 0 RVP 343
-- PVP→
VT 385 RVS 410 PVP→
VT 393 RVS 410 PVP→
VT 388 RVS 413 PVP→
VT 390 PVP→
VT 375

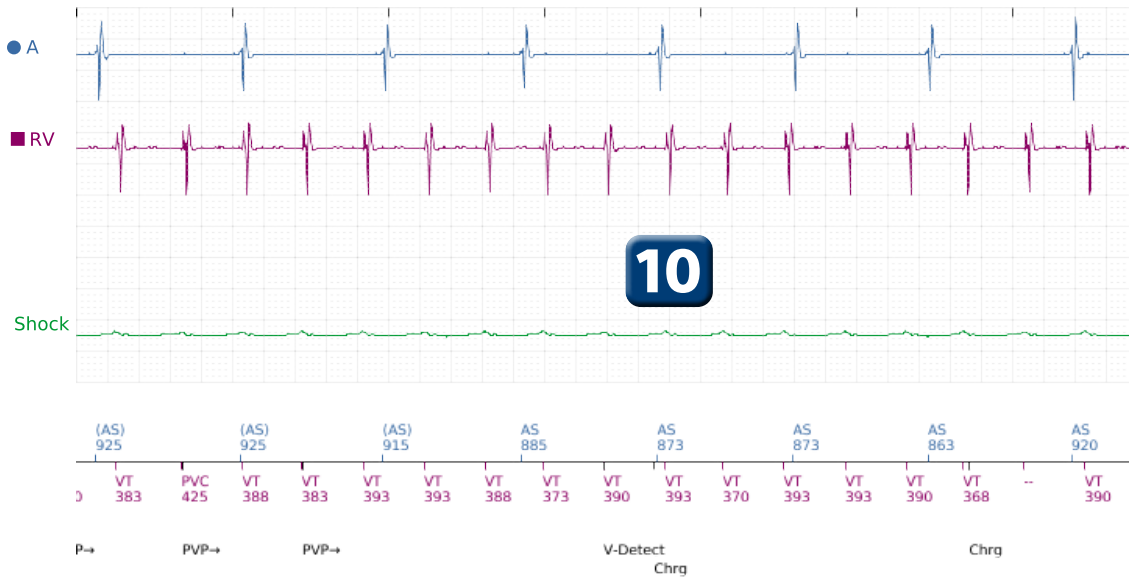

A
RV
7
Shock
(AS) 918
AS 918
AS 928
AS 928
AS 910
--
AS 875
VT 395 VT 395 VT 393 VT 383 VT 390 VT 400 VT 390
LVP 0 RVP 353
LVP 0 RVP 353
LVP 0 RVP 343
LVP 0 RVP 333
LVP 0 RVP 323
LVP 0 RVP 313
LVP 0 RVP 303
LVP 0 RVP 293
-- PVP→
RVS 448 PVC 430 PVP→
PVP→
V-Detect

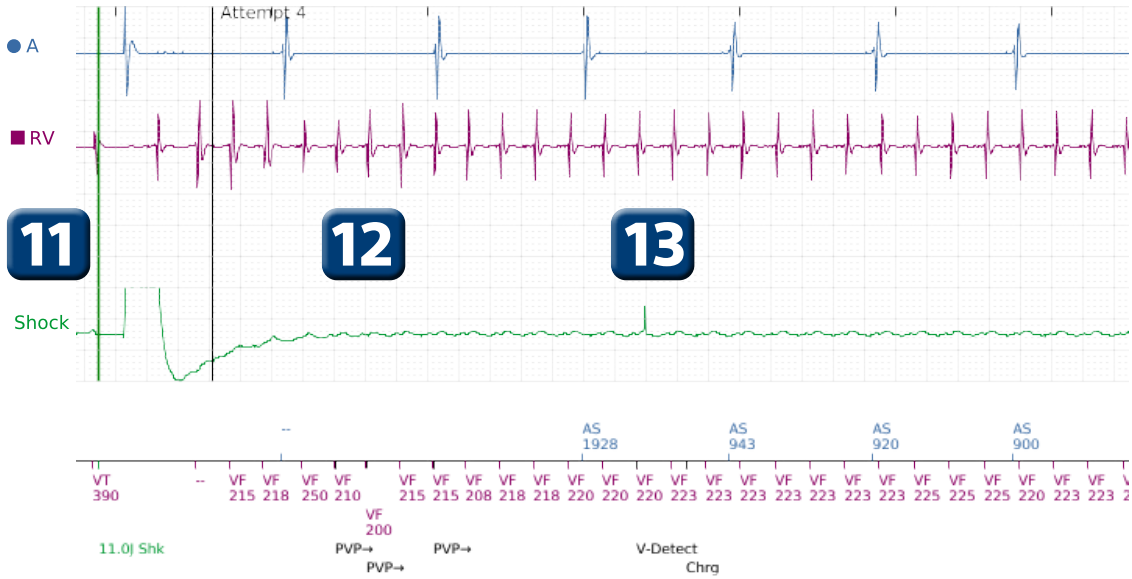

A
RV
Shock
(AS) 870
AS 873
(AS) 870
(AS) 913
(AS) 925
AS 938
AS 918
AS 913
RVS 428
VT 398
RVS 425
VT 393
VT 388
VT 395
VT 400
VT 390
PVC 428
VT 388
VT 388
VT 395
VT 400
VT 390
LVP 0
RVP 355
LVP 0
RVP 355
LVP 0
RVP 345
PVP→
PVP→
PVP→
PVP→
V-Detect


A
RV
8
Shock
AS 888
AS 888
--
(AS) 878
(AS) 943
(AS) 940
(AS) 920
LVP 0
RVP 325
LVP 0
RVP 315
LVP 0
RVP 305
LVP 0
RVP 295
LVP 0
RVP 285
--
RVS 448
PVC 430
RVS 428
VT 393
RVS 413
VT 393
VT 393
VT 395
PVC 403
RVS 413
PVC 403
PVP→
PVP→
PVP→
PVP→
PVP→
PVP→


A
RV
Shock
9
(AS) 918
(AS) 900
(AS) 885
(AS) 880
AS 878
AS 878
AS 1868
VT 393
VT 400
VT 385
RVS 403
VT 390
VT 400
VT 363
VT 393
VT 395
VT 393
VT 370
VT 390
LVP 0
RVP 350
RVP 350
RVP 340
RVP 330
RVP 320
RVP 310
PVP→
PVP→
PVP→
V-Detect


Attempt 3
A
RV
Shock
AS 938
--
(AS) 890
(AS) 875
(AS) 878
(AS) 860
(AS) 940
LVP 0
RVP 290
RVP 280
RVP 270
RVS 455
VT 365
RVS 433
VT 368
RVS 430
VT 388
RVS 428
VT 390
RVS 405
VT 378
PVC 403
VT 390
PVP→
PVP→
PVP→
PVP→
PVP→
PVP→


A
RV
10
Shock
(AS) 925
(AS) 925
(AS) 915
AS 885
AS 873
AS 873
AS 863
AS 920
VT 383
PVC 425
VT 388
VT 383
VT 393
VT 393
VT 388
VT 373
VT 390
VT 393
VT 370
VT 393
VT 393
VT 390
VT 368
--
VT 390
P→
PVP→
PVP→
V-Detect
Chrg
Chrg


Attempt 4
A
RV
11
12
13
Shock
--
AS 1928
AS 943
AS 920
AS 900
VT 390
--
VF 215
VF 218
VF 250
VF 210
VF 200
VF 215
VF 215
VF 208
VF 218
VF 218
VF 220
VF 220
VF 220
VF 223
VF 223
VF 223
VF 223
VF 223
VF 223
VF 223
VF 225
VF 225
VF 225
VF 220
VF 223
VF 223
11.0J Shk
PVP→
PVP→
PVP→
PVP→
V-Detect
Chrg


A
RV
Shock
AS 888
AS 885
AS 950
[AS]
[AS]
[AS]
[AS]
[AS]

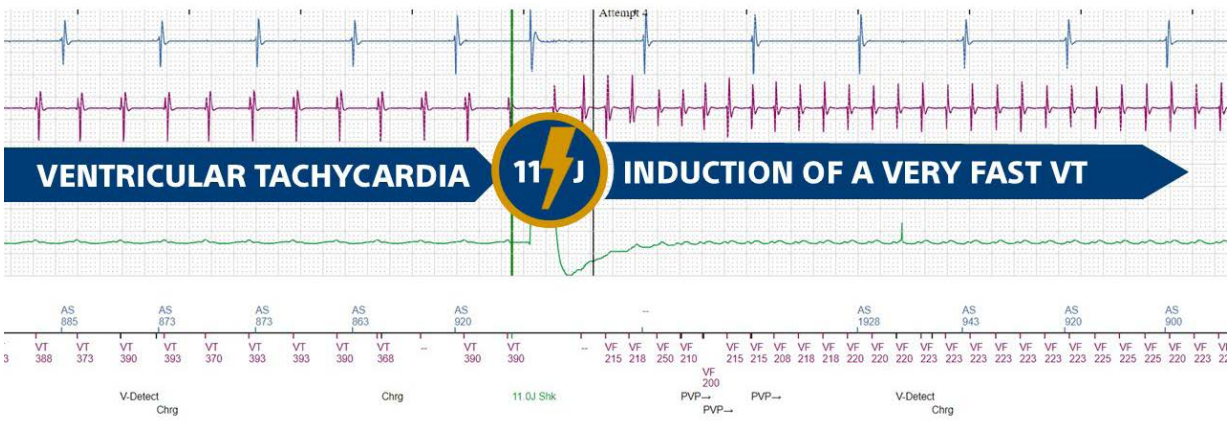

A
RV
14
Shock
[AS]
--
AS 1003
AP 855
AP 825
LVP 0
RVP 1268
RVP 855
RVP 855
Chrg
41.0J Shk
PVP→

Points to remember

- the amplitude of the first shock in the VT zone can be programmed at maximum energy or at a lower amplitude (in the order of 10 to 15 Joules)
- there are a number of advantages to programming a first shock of moderate amplitude (10-15 Joules): 1) this amplitude is very often sufficient to terminate a VT episode; 2) the charge time for this amplitude is very short, even if the few seconds difference in comparison to a maximum amplitude shock may not be clinically important when the shock occurs after 3 burst +/- 3 ramp sequences (more than one minute of arrhythmia);

3) power consumption is lower for a shock at 10 Joules versus 41 Joules, even if battery usage is only slightly affected if a limited number of shocks are delivered; 4) even though for most VT episodes the shock is delivered while the patient is still conscious, the painful nature of the shock contributes minimally to decision-making regarding the amplitude of the first shock, since it is difficult to demonstrate a direct relationship between the amplitude of the shock delivered and the amplitude of the pain caused; 5) various studies have demonstrated the deleterious nature of an electric shock and its association with an adverse prognosis ; it therefore seems logical to think that a 10-15 Joule shock will have fewer negative consequences than a 41 Joule shock, and it seems advisable to choose the least traumatic therapy possible.

- this tracing shows the main drawback of programming a low-amplitude shock (11 Joules) in the VT zone: pro-arrhythmogenic risk and acceleration of the arrhythmia (concept of upper limit of vulnerability); in this patient, the shock has the opposite effect to what was intended; below a certain value, which varies according to the patient and is directly linked to the defibrillation «threshold», not only can a shock prove ineffective in terminating an arrhythmia, but it can also accelerate and cause degeneration of a monomorphic VT into a polymorphic arrhythmia, compromising the patient's short-term prognosis.



This figure shows how a medium-amplitude shock accelerates a monomorphic VT at 160 beats/minute into a very rapid ventricular flutter.

14 Maximum output shock in the VT zone

Patient

- 51-year-old man implanted with an Incepta single-chamber defibrillator

Summary

- episode classified in the VT zone
- 3 bursts + 3 ramps + 1 shock of 41 Joules

EGM layout

1 probable ventricular tachycardia (clear change in morphology on the shock channel)

2 at the end of the duration, a burst of 10 complexes at a fixed rate

3 ineffective burst and ongoing arrhythmia

4 second burst

5 third burst

6 first ramp

7 second ramp

8 third ramp

9 next therapy is an electric shock; capacitor charging begins

10 41 Joule electric shock delivered on the second rapid ventricular cycle (2/3 rapid cycle criterion verified) at the end of the diversion window

11 effective shock

LATITUDE™ Patient Management - Event Detail Report	Report Created: 23 Jan 2023

Boston Scientific

Date of Birth:
Device: **INCEPTA ICD F160**
Clinic:
Search Tags:
Tachy Mode: **Monitor + Therapy**

Latest Device Transmission: **16 Jan 2023 09:44 CET**
Last Office Interrogation:
Implant Date:
Patient Group:

V-3: 20 Jul 2013 11:14, VT, V Rate: 211 min^{-1}

Detail

VT Event Onset

Avg V Rate	211 min^{-1}
Detection	Rhythm ID

At V-Detect

Avg V Rate	209 min^{-1}
Rate Zone	VT
RhythmID Correlated	False
RhythmMatch™	
SRD Met	False
ATP Timeout	False

Attempt 1, Burst V ATP

Elapsed Time	00:00:06
ATP Information	
Number of Bursts	3

At V-Detect

Avg V Rate	211 min^{-1}
Rate Zone	VT
ATP Timeout	False

Attempt 2, Ramp V ATP

Elapsed Time	00:00:25
ATP Information	
Number of Bursts	3

At V-Detect

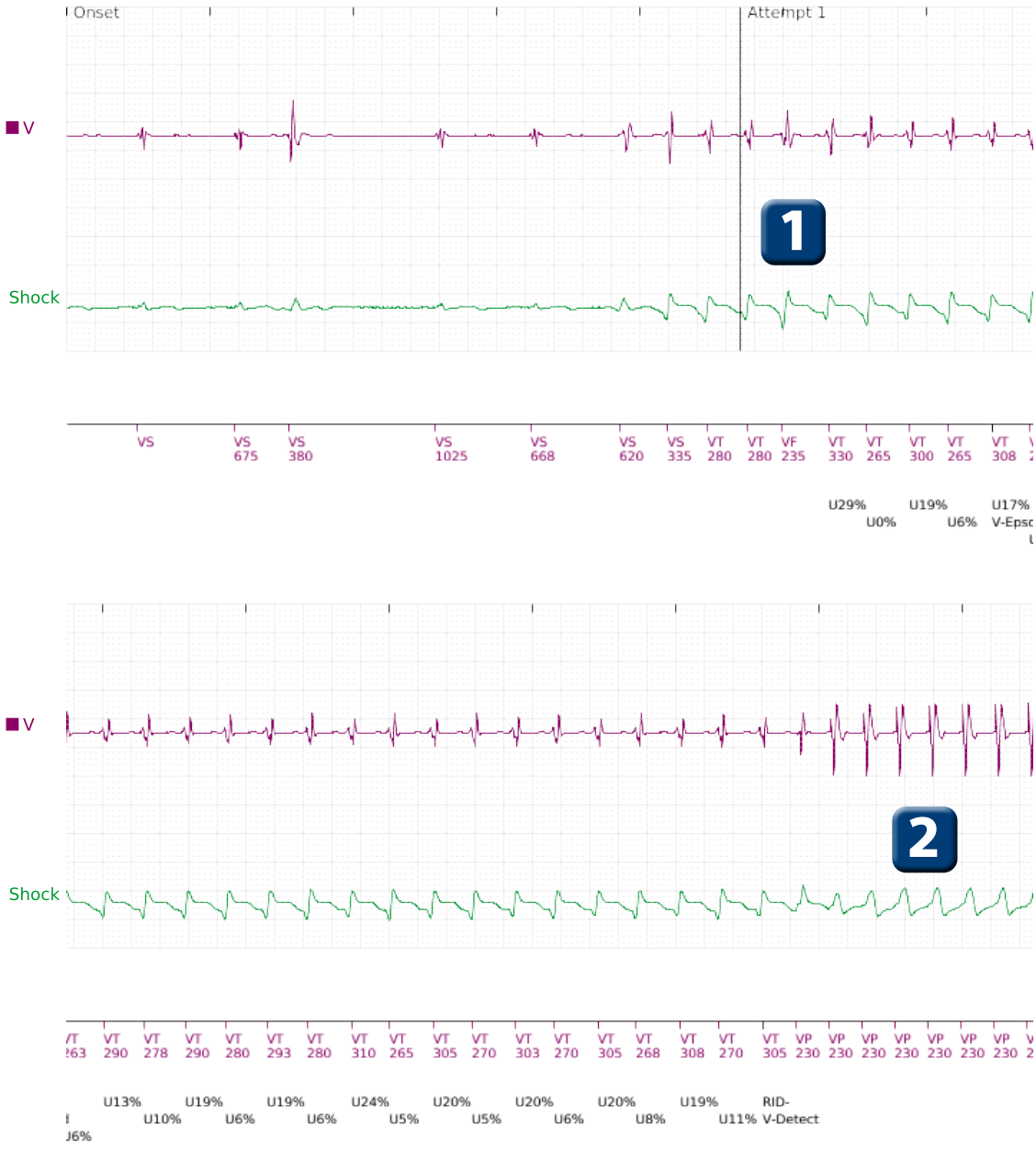
Avg V Rate	209 min^{-1}
Rate Zone	VT
ATP Timeout	False

Attempt 3, 41 J V Shock

Elapsed Time	00:00:44
Shock Information	
Charge Time	9.0 s
Lead Impedance	53 Ω
Lead Polarity	Initial

Event Ended 00:01:24

EGM displayed at 25mm per second


Onset
Attempt 1
V
1
Shock
VS
VS 675
VS 380
VS 1025
VS 668
VS 620
VS 335
VT 280
VT 280
VF 235
VT 330
VT 265
VT 300
VT 265
VT 308
U29%
U0%
U19%
U6%
U17%
V-Epsc
V
2
Shock
VT 263
VT 290
VT 278
VT 290
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VT 293
VT 280
VT 310
VT 265
VT 305
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VT 270
VT 305
VT 268
VT 308
VT 270
VT 305
VP 230
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U8%
U19%
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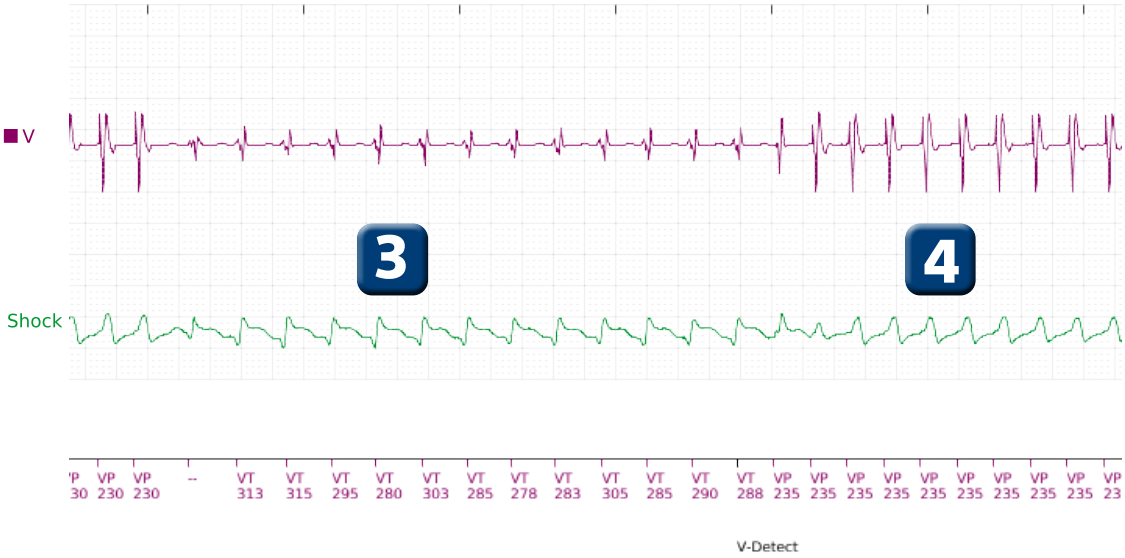
J6%


V
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Shock
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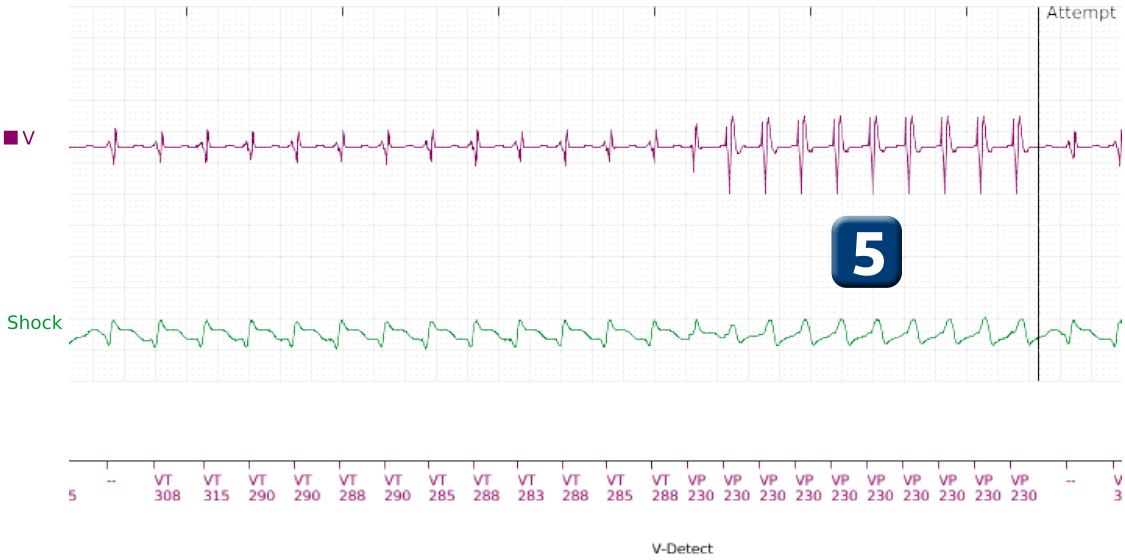
V-Detect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Shock
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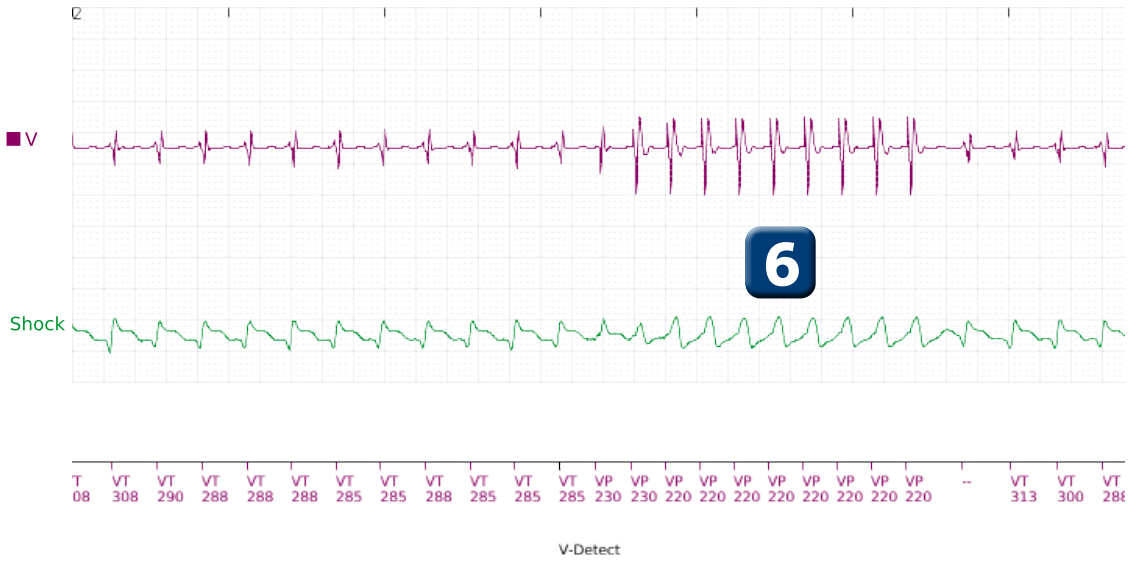
V-Detect


V
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Shock
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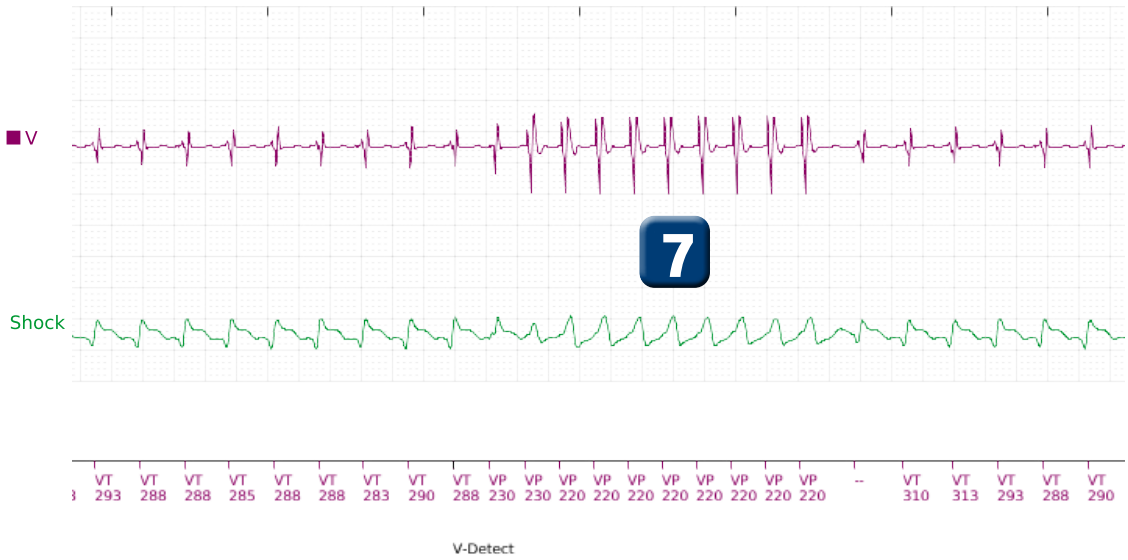
08 308 290 288 288 288 285 285 288 285 285 285 230 230 220 220 220 220 220 220 220 220 313 300 288
V-Detect


V
7
Shock
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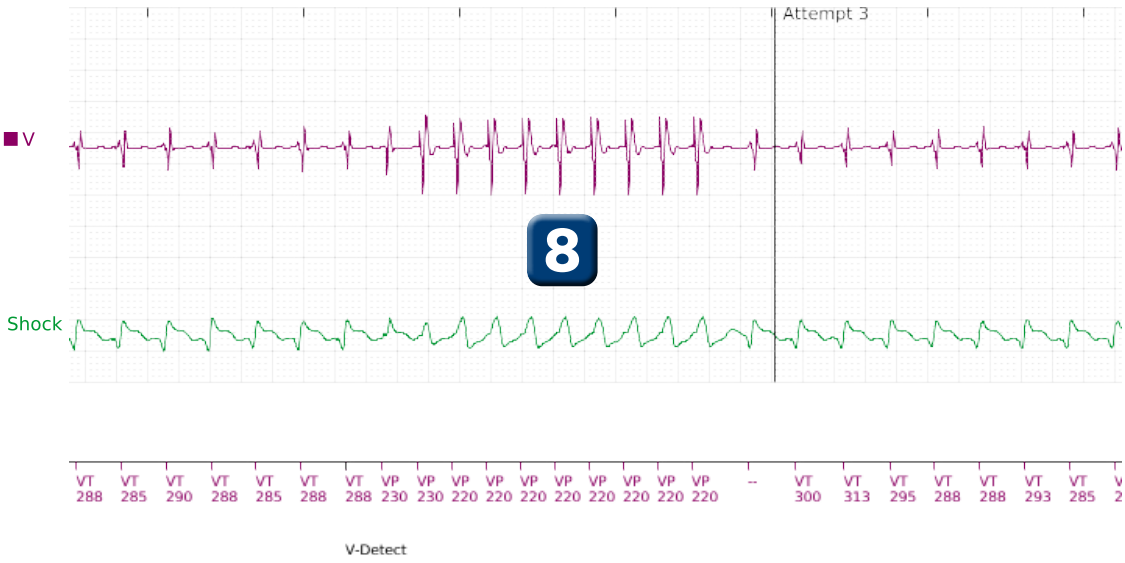
293 288 288 285 288 288 283 290 288 230 230 220 220 220 220 220 220 220 220 310 313 293 288 290
V-Detect


Attempt 3
V
8
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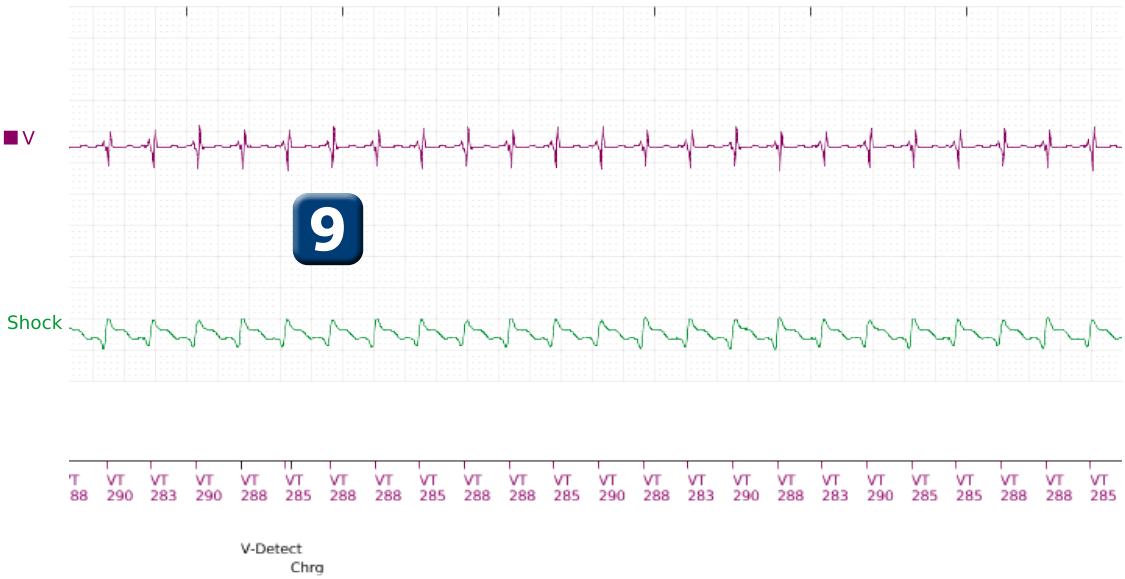
V-Detect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9
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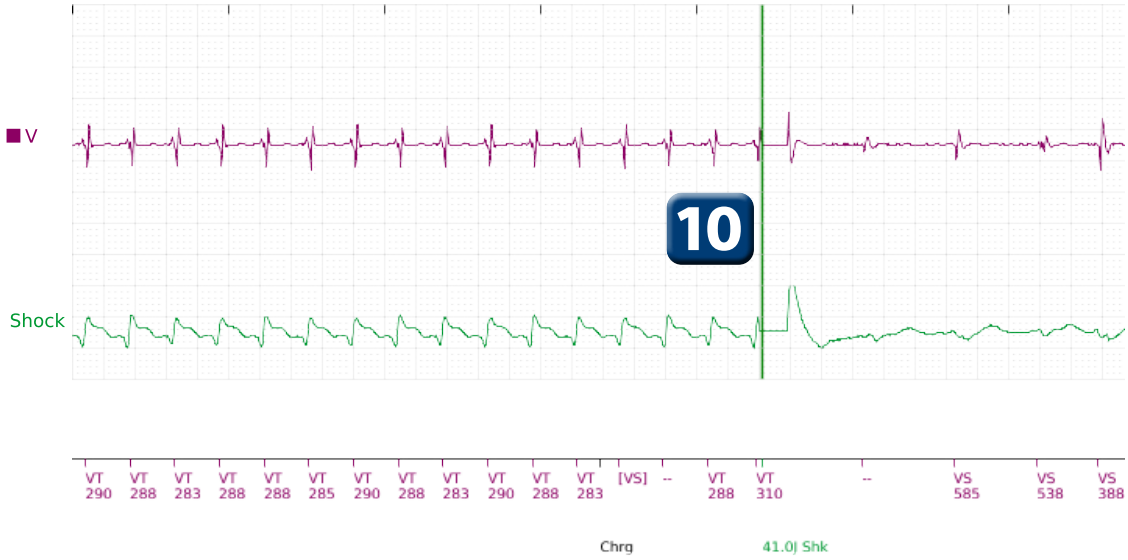
V-Detect
Chrg


V
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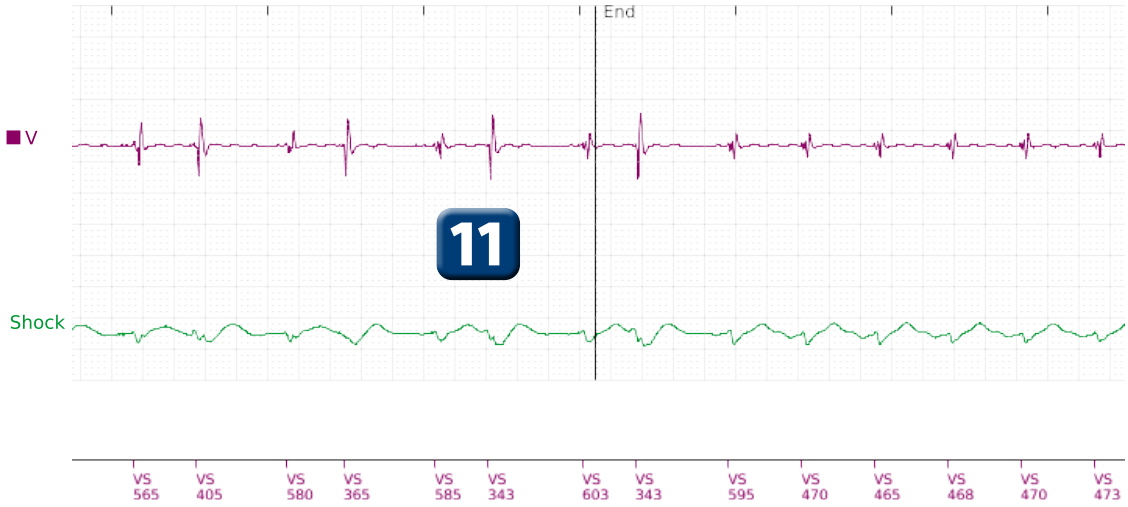
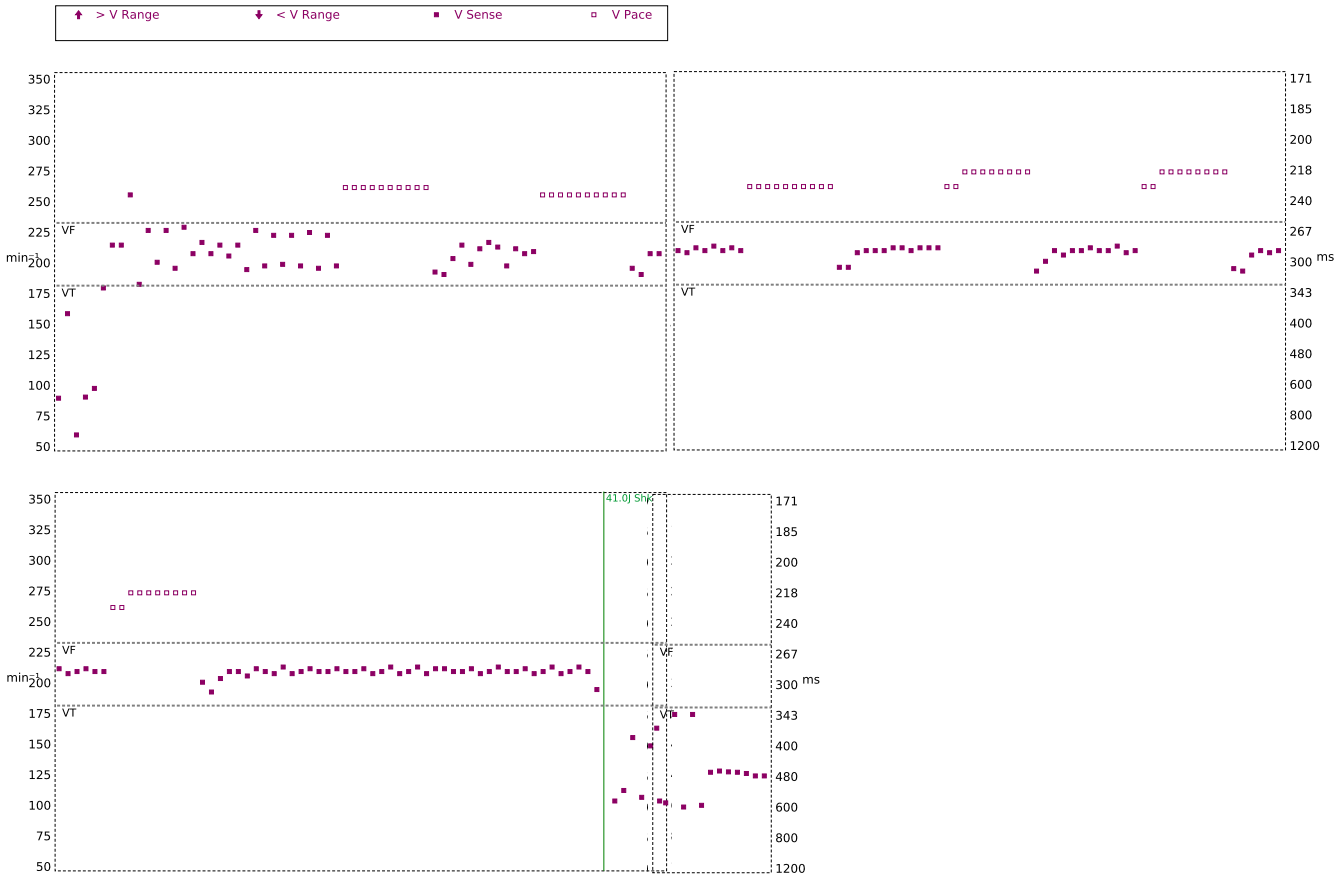

End
V
11
Shock
VS 565 VS 405 VS 580 VS 365 VS 585 VS 343 VS 603 VS 343 VS 595 VS 470 VS 465 VS 468 VS 470 VS 473


> V Range
< V Range
V Sense
V Pace
350
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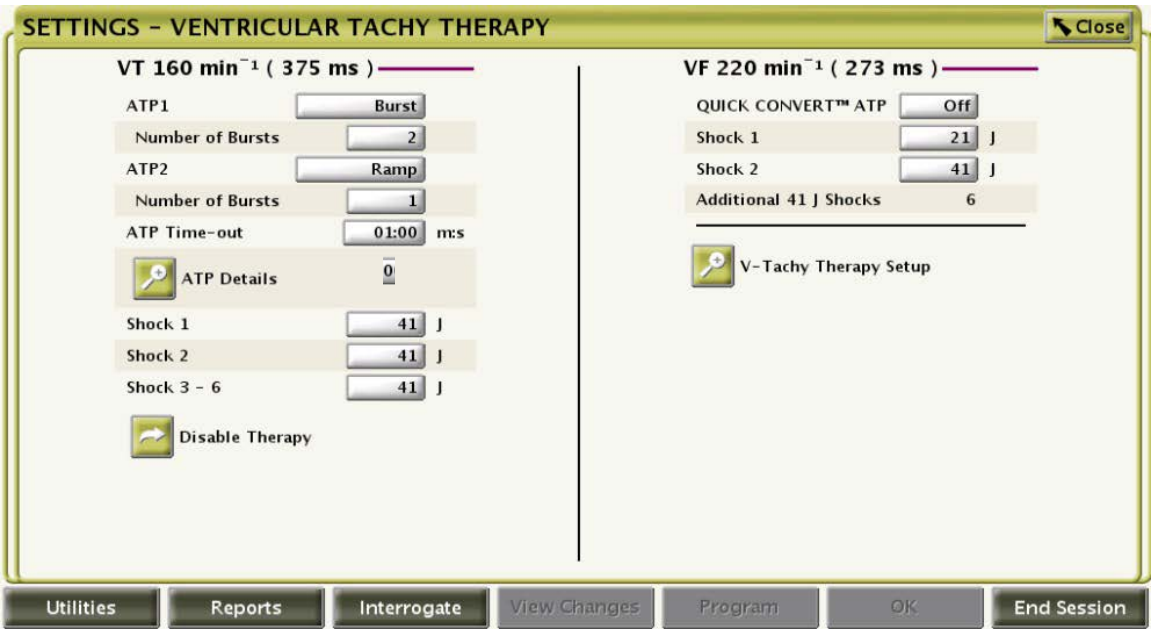
300
275
250
225
200
175
150
125
100
75
50
min-1
VF
VT
171
185
200
218
240
267
300
343
400
480
600
800
1200
ms
41.0J Shk

Points to remember

- this plot illustrates the other option for programming the amplitude of the first shock in the VT zone
- empirical programming of a first shock of maximum amplitude reduces the risk of pro-arrhythmogenic effects and increases the probability of terminating VT on the first attempt, thereby minimizing the number of shocks delivered and increasing the probability of terminating AF if the shock is inappropriate



Example of programming in the VT zone with therapies of increasing aggressiveness; burst then ramp then shock (maximum amplitude from the outset); 8 shocks can be programmed for the VF zone, 6 shocks for the VT zone and 5 shocks for the VT-1 zone.

15 Anti-tachycardia pacing in the VT zone with acceleration into the VF zone

Patient

- 72-year-old male implanted with a Momentum triple-chamber defibrillator

Summary

- episode initially classified in the VT zone then in the VF zone
- 1 burst + 1 shock of 41 Joules

EGM layout

1 ventricular tachycardia with atrioventricular dissociation

2 at the end of duration, burst of 10 complexes at fixed rate

3 acceleration of arrhythmia into the VF zone

4 diagnosis of a VF episode and charging of capacitors

5 arrhythmia becomes polymorphic

6 shock of 41 Joules

7 arrhythmia termination

LATITUDE™ Patient Management - Event Detail Report	Report Created: 23 Jan 2023

Boston Scientific

Date of Birth:
Device: **MOMENTUM X4 CRT-D**
Clinic:
Search Tags:
Tachy Mode: **Monitor + Therapy**

Latest Device Transmission: **20 Dec 2021 02:01 CET**
Last Office Interrogation: **24 Nov 2021**
Implant Date:
Patient Group:

V-2: 24 Nov 2021 10:15, VT, A Rate: 82 min^{-1}, V Rate: 209 min^{-1}

Detail

VT Event Onset

Avg A Rate	82 min^{-1}
Avg V Rate	209 min^{-1}
Detection	Rhythm ID
Template	21 Nov 2021 20:55
RhythmMatch™ Threshold	94 %

At V-Detect

Avg A Rate	79 min^{-1}
Avg V Rate	204 min^{-1}
Rate Zone	VT
Stability	4 ms
V>A Rate	True
AFib	False
RhythmID Correlated	False
RhythmMatch™	64 %
SRD Met	(False, Off)
ATP Timeout	False

Attempt 1, Burst V ATP

Elapsed Time	00:00:10
ATP Information	
Number of Bursts	1

At V-Detect

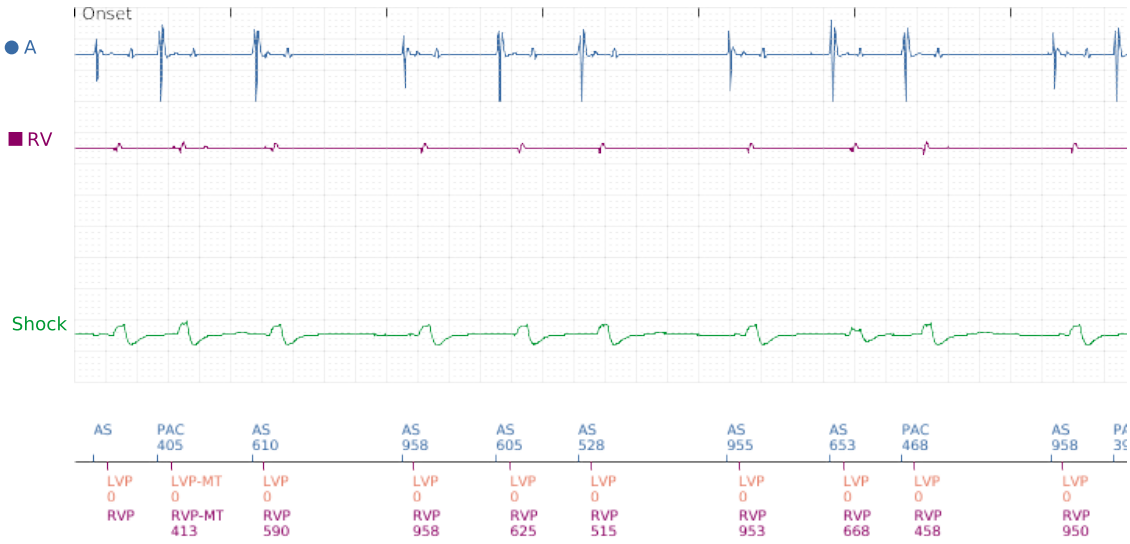
Avg A Rate	77 min^{-1}
Avg V Rate	294 min^{-1}
Rate Zone	VF
ATP Timeout	False

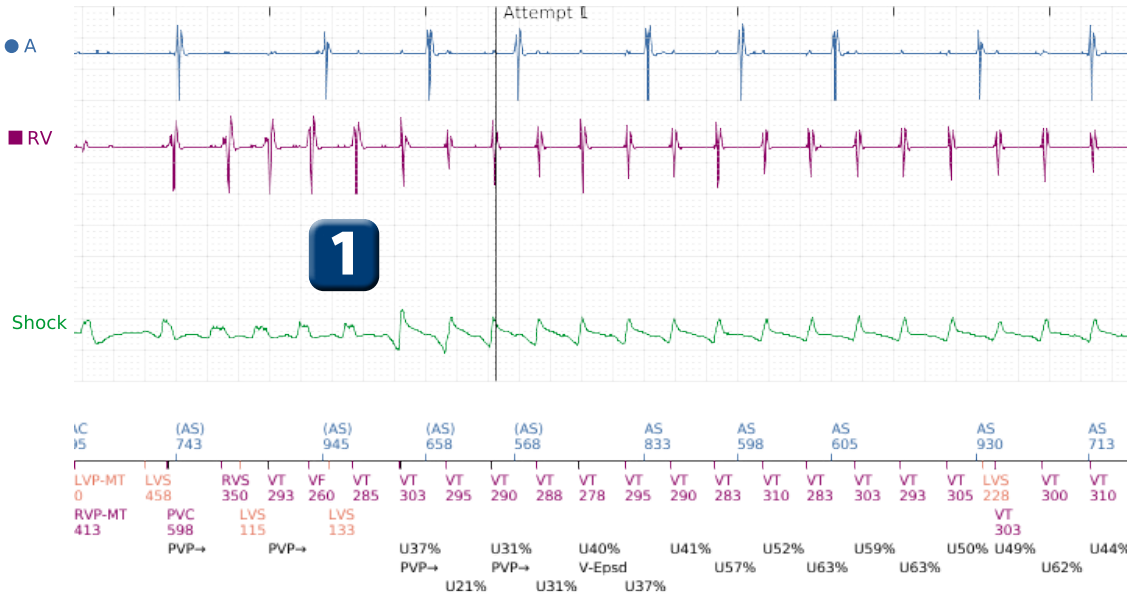
Attempt 2, 41 J V Shock

Elapsed Time	00:00:16
Shock Information	
Charge Time	9.4 s
Lead Impedance	38 Ω
Lead Polarity	Initial

Event Ended 00:00:58

EGM displayed at 25mm per second


Onset
A
RV
Shock
AS 405 AS 610 AS 958 AS 605 AS 528 AS 955 AS 653 PAC 468 AS 958
PAC
LVP 0 RVP
LVP-MT 0 RVP-MT 413
LVP 0 RVP 590
LVP 0 RVP 958
LVP 0 RVP 625
LVP 0 RVP 515
LVP 0 RVP 953
LVP 0 RVP 668
LVP 0 RVP 458
LVP 0 RVP 950


Attempt 1
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(AS) 743 (AS) 945 (AS) 658 (AS) 568 AS 833 AS 598 AS 605 AS 930 AS 713
LVP-MT 0 RVP-MT 413
LVS 458 PVC 598
RVS 350 LVS 115
VT 293 VF 260 LVS 133
VT 285
VT 303 VT 295 VT 290 VT 288 VT 278 VT 295 VT 290 VT 283 VT 310 VT 283 VT 303 VT 293 VT 305
LVS 228 VT 303
VT 300 VT 310
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PVP→
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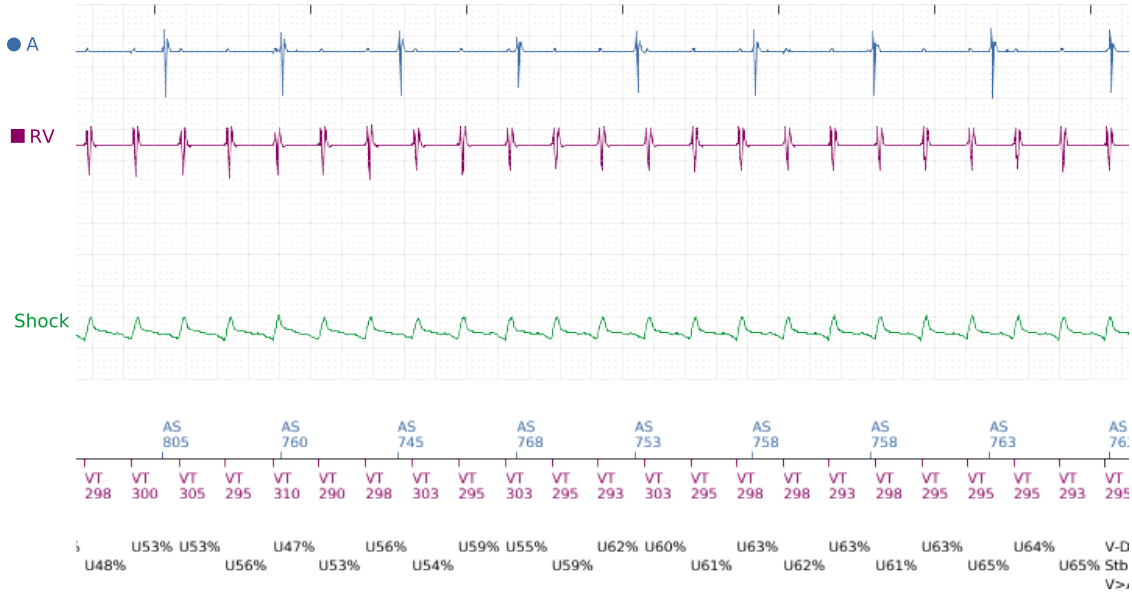
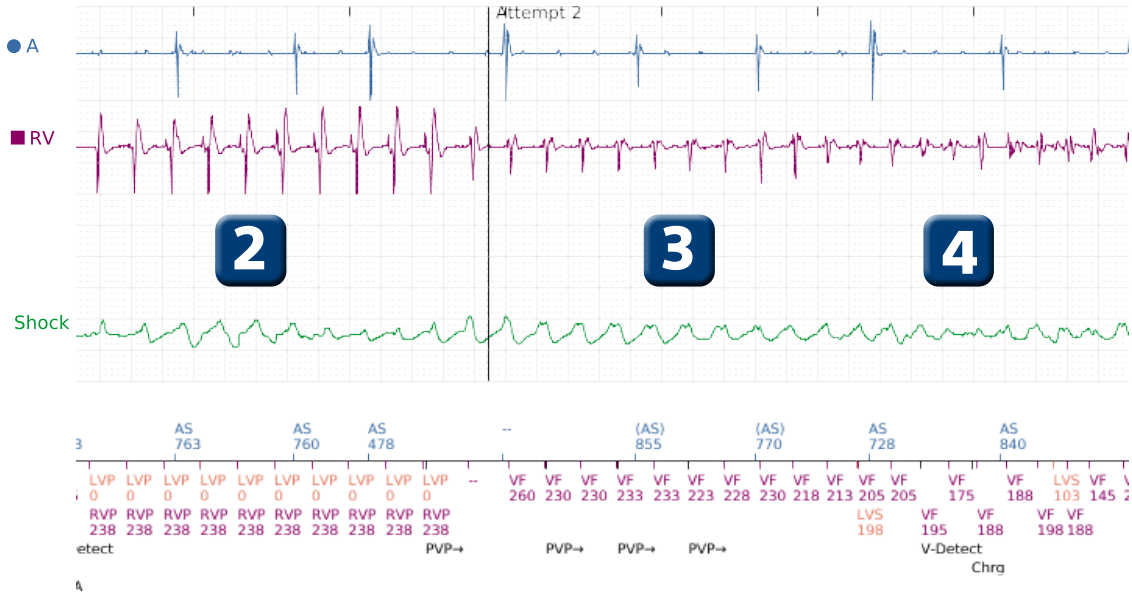
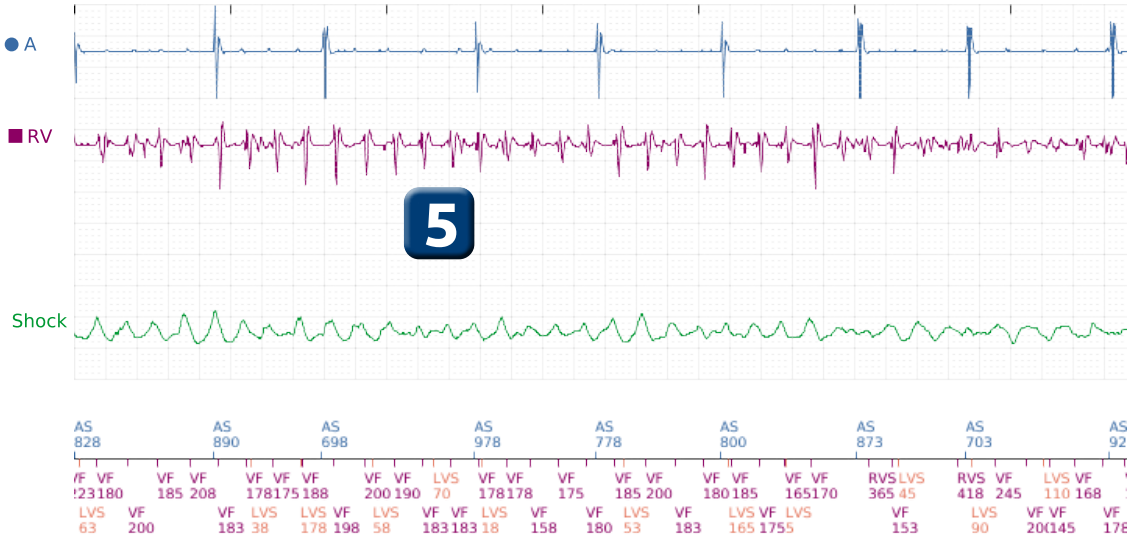
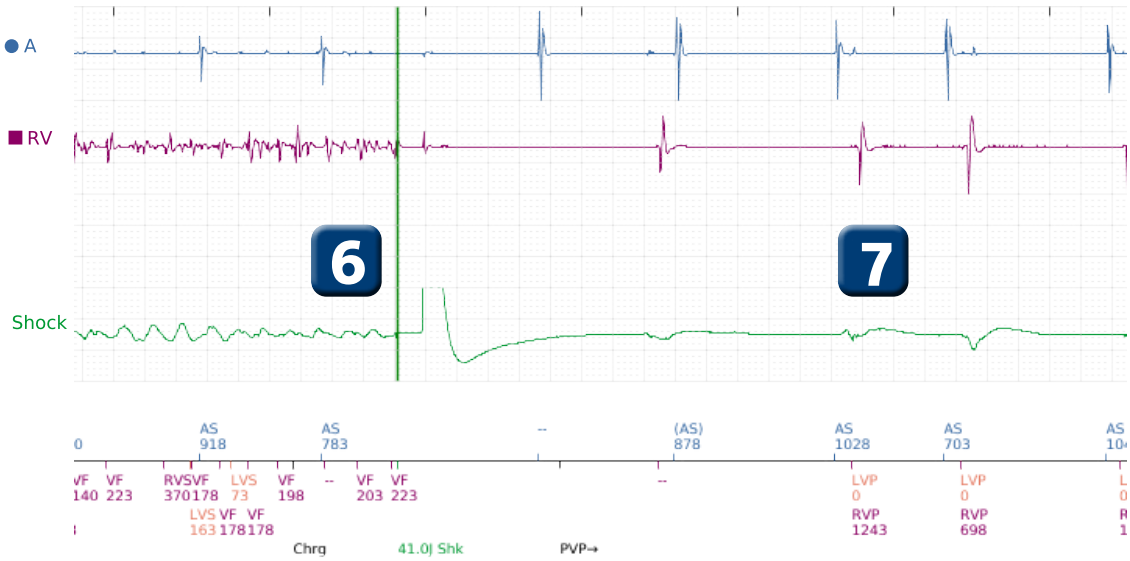
U31% PVP→ U31%
U40% V-Epsd U37%
U41% U57%
U52% U63%
U59% U63%
U50% U49% U62%
U44%

LATITUDE™ Patient Management - Event Detail Report 23 Jan 2023

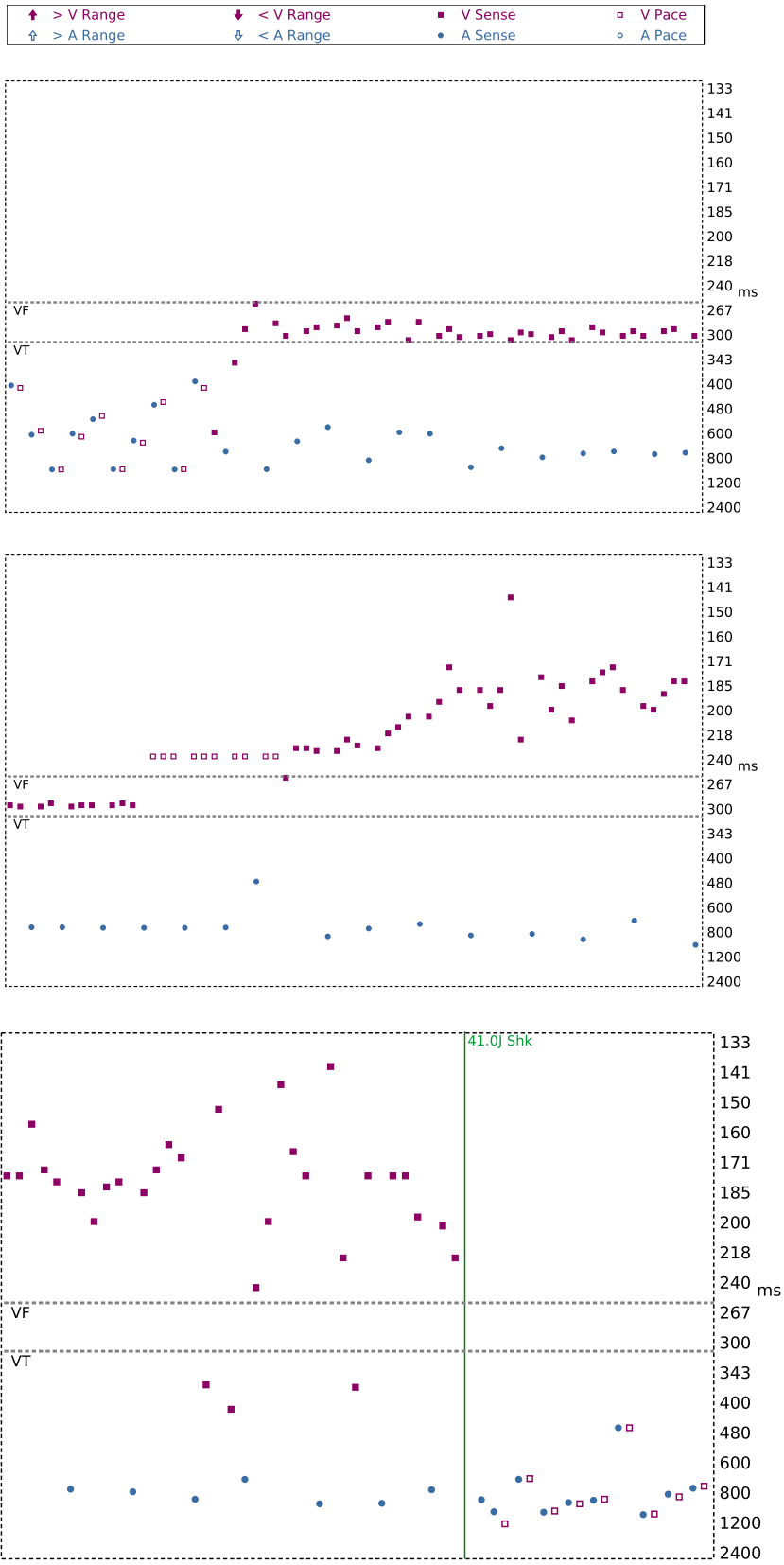





A
RV
5
Shock

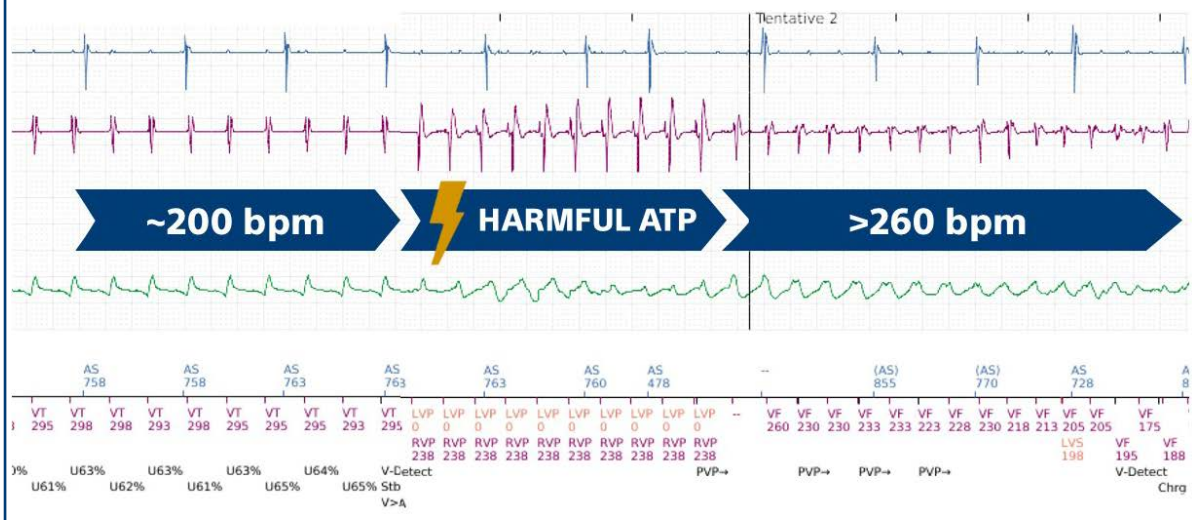

A
RV
6
7
Shock
Chrg
41.0J Shk
PVP→

LATITUDE™ Patient Management - Event Detail Report 23 Jan 2023



Points to remember

- there are 3 reasons why a shock may be delivered following the detection of an arrhythmia in the VT zone: 1) the electric shock is the first therapy programmed in the VT zone; 2) previous therapies (anti-tachycardia stimulation bursts) have proved ineffective; 3) an anti-tachycardia pacing burst accelerates the tachycardia into the VF zone, as in this example.
- acceleration of VT and degeneration into VF are well-described complications following an anti-tachycardia pacing sequence, with an incidence of approximately 1 to 5% ; this justifies the absolute necessity of programming shocks as a back-up in the VF zone; the efficacy and safety of anti-tachycardia pacing are inversely related; a greater number of tachycardias can be terminated with a more aggressive protocol (shorter coupling intervals, more cycles per sequence, more sequences) but with an increased risk of acceleration
- anti-tachycardia pacing can 1) accelerate a tachycardia with the same morphology as the previous one, 2) accelerate a tachycardia with a different morphology, or 3) cause an organized tachycardia to degenerate into VF.



This figure shows how the anti-tachycardia pacing sequence accelerates a monomorphic VT at 200 beats/minute into a very rapid ventricular flutter and then into VF.

10 references to know

1 Poole JE, Johnson GW, Hellkamp AS et al. Prognostic importance of defibrillator shocks in patients with heart failure. N Engl J Med 2008 : ***SCD-HeFT study which shows that the mortality rate for patients who have experienced appropriate shock is five times higher, and twice as high for those who have experienced inappropriate shock***

2 Wathen MS, DeGroot PJ, Sweeney MO et al. Prospective randomized multicenter trial of empirical antitachycardia pacing versus shocks for spontaneous rapid ventricular tachycardia in patients with implantable cardioverter-defibrillators: Pacing Fast Ventricular Tachycardia Reduces Shock Therapies (PainFREE Rx II) trial results. Circulation 2004 : ***Pain Free II study, which shows the effectiveness of anti-tachycardia pacing for rapid tachycardia without an increase in the number of syncopes***

3 Wilkoff BL, Ousdigian KT, Sterns LD et al. A comparison of empiric to physician-tailored programming of implantable cardioverter-defibrillators: results from the prospective randomized multicenter EMPIRIC trial. J Am Coll Cardiol 2006 : ***the Empiric study, which demonstrates the benefits of systematic and empirical programming of antitachycardia pacing compared to a strategy in which the effectiveness of ATP must first be tested in the electrophysiology laboratory***

4 Gulizia MM, Piraino L, Scherillo M et al. A randomized study to compare ramp versus burst antitachycardia pacing therapies to treat fast ventricular tachyarrhythmias in patients with implantable cardioverter defibrillators: the PITAGORA ICD trial. Circ Arrhythm Electrophysiol 2009 : ***the Pitagora study, which shows bursts to be superior to ramps for reducing fast TVs (cycles between 240 and 320 ms)***

5 Schoels W, Steinhaus D, Johnson WB et al. Optimizing implantable cardioverter-defibrillator treatment of rapid ventricular tachycardia: antitachycardia pacing therapy during charging.

Heart Rhythm 2007 ***:this study validates the interest and safety of issuing an ATP during the load on fast TVs***

6 Brignole M, Occhetta E, Bongiorni MG, et al. SAFE-ICD Study Investigators. Clinical evaluation of defibrillation testing in an unselected population of 2,120 consecutive patients undergoing first implantable cardioverter-defibrillator implant. J Am Coll Cardiol. 2012 : ***this study shows no difference in terms of complications and sudden death in a group that underwent a defibrillation test at the end of the implantation versus a group that did not undergo the test***

7 Steinhaus DM, Cardinal DS, Mongeon L, et al. Internal defibrillation: pain perception of low energy shocks. Pacing Clin Electrophysiol. 2002 : ***this study shows the absence of difference in the patient's perception when a shock of 10 Joules is delivered versus one maximum shock***

8 Kroll MW, Efimov IR, Tchou PJ. Present understanding of shock polarity for internal defibrillation: the obvious and non-obvious clinical implications. Pacing Clin Electrophysiol. 2006 : ***meta-analysis which shows that an anodal shock results in defibrillation thresholds that are on average slightly lower than a cathodal shock***

9 Sweeney MO. Antitachycardia pacing for ventricular tachycardia using implantable cardioverter defibrillators: Pacing Clin Electrophysiol. 2004 : ***this article covers the physiopathological bases and the results of studies demonstrating the benefits of anti-tachycardia pacing***

10 Strik M, Ramirez FD, Welte N, Bonnin T, Abu-Alrub S, Eschalier R, Haïssaguerre M, Ritter P, Ploux S, Bordachar P. Progressive implantable cardioverter-defibrillator therapies for ventricular tachycardia: The efficacy and safety of multiple bursts, ramps, and low-energy shocks. Heart Rhythm. 2020. ***Study from our lab showing successrate of 63% after 1 burst and 89% after 6 bursts.***

Chapter 3

Discrimination

Intro Basics of Boston Scientific™ discrimination

Indications

- Discrimination for supra-ventricular arrhythmias is only anticipated in patients likely to present with supra-ventricular arrhythmia in the VT detection zone. For patients with complete AV block or a low Wenckebach point, discrimination (rate-only) is not programmed.
- Before considering discrimination, the first step is to think carefully about the rate cutoffs for the treatment zones: if the lower limit of the treatment zone is set at a high heart rate, there is a lower risk of interference from supra-ventricular arrhythmias

Special aspects

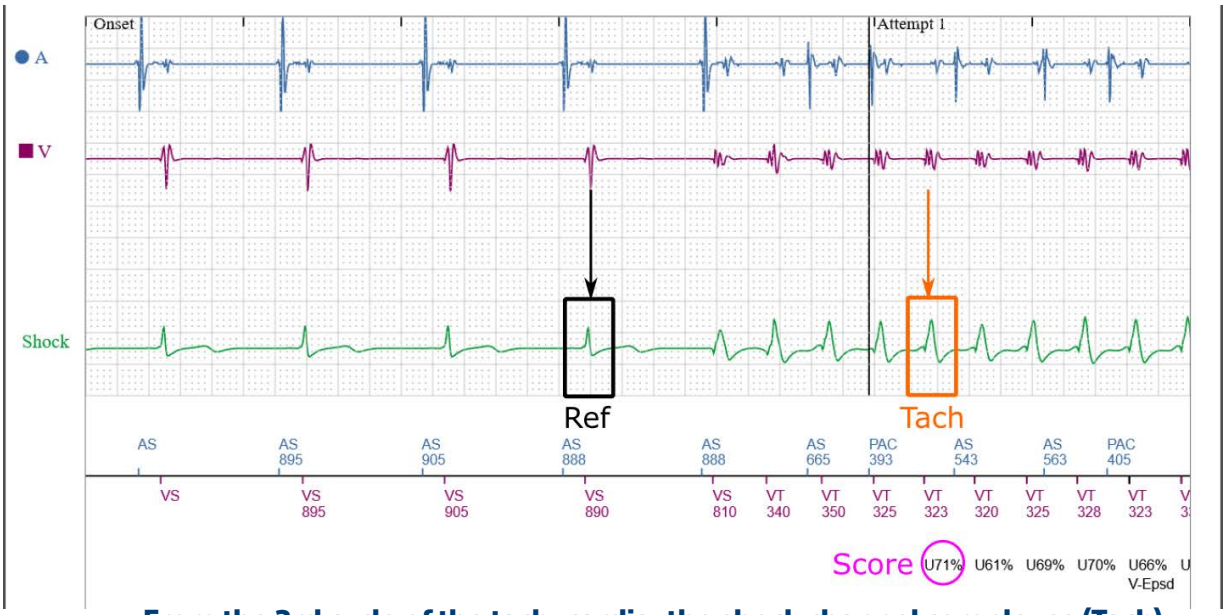
- Discrimination cannot be applied in VF zones.
- Discrimination cannot be applied in VT monitor zones.
- There is no inhibitory discrimination behind an ATP.
- In post-shock mode, the morphology criterion (Rhythm ID) is no longer available.

Algorithms

1 **Comparaison of A et V rhythms :** comparison of the average A and V rates (calculated over the last 10 beats before the end of the duration). If the V rate is 10 bpm higher than the A rate, VT is diagnosed and treatment is given.

2 **Ventricular signal morphology (Rhythm ID/vector correlation):** comparison of the morphology of reference ventricular signals (intrinsic depolarization) with ventricular signals acquired during tachycardia. The analysis is carried out on the shock channel signal (Coil-can, also known as Far-Field). If three of the last ten ventricular complexes immediately preceding the end of the duration are sufficiently similar (percentage

match) to the reference template, the algorithm considers the tachycardia to be supra-ventricular. The similarity threshold is nominally set to 94%, and is programmable. The rhythm ID reference can be acquired manually or automatically.



From the 3rd cycle of the tachycardia, the shock channel complexes (Tach) are compared with the morphology of the reference complex (Ref). The signal analysis windows are centred on the bipolar V channel detections. The similarity score appears below the markers (Score).

3 **Sudden onset :** looks for a jump in rate at the start of the tachycardia. A gradual onset is consistent with sinus tachycardia progressively entering the VT zone.

4 **Stability :** tachycardia analysis of R-R interval stability. Stability corresponds to the variance of the RR intervals (between the 5 intervals preceding the V-Episode marker and the intervals following the V-Episode marker until the end of the duration). If this variance is greater than the programmed stability limit, then the rhythm is considered unstable (AF).

5 **AFib rate threshold :** search for AF on the atrial channel. When 6/10 A intervals are faster than the AFib rate threshold (170/min nominal), the algorithm validates the presence of AF. To maintain the diagnosis during the analysis, 4/10 intervals must remain faster than the Fib A frequency threshold.

Single chamber algorithms

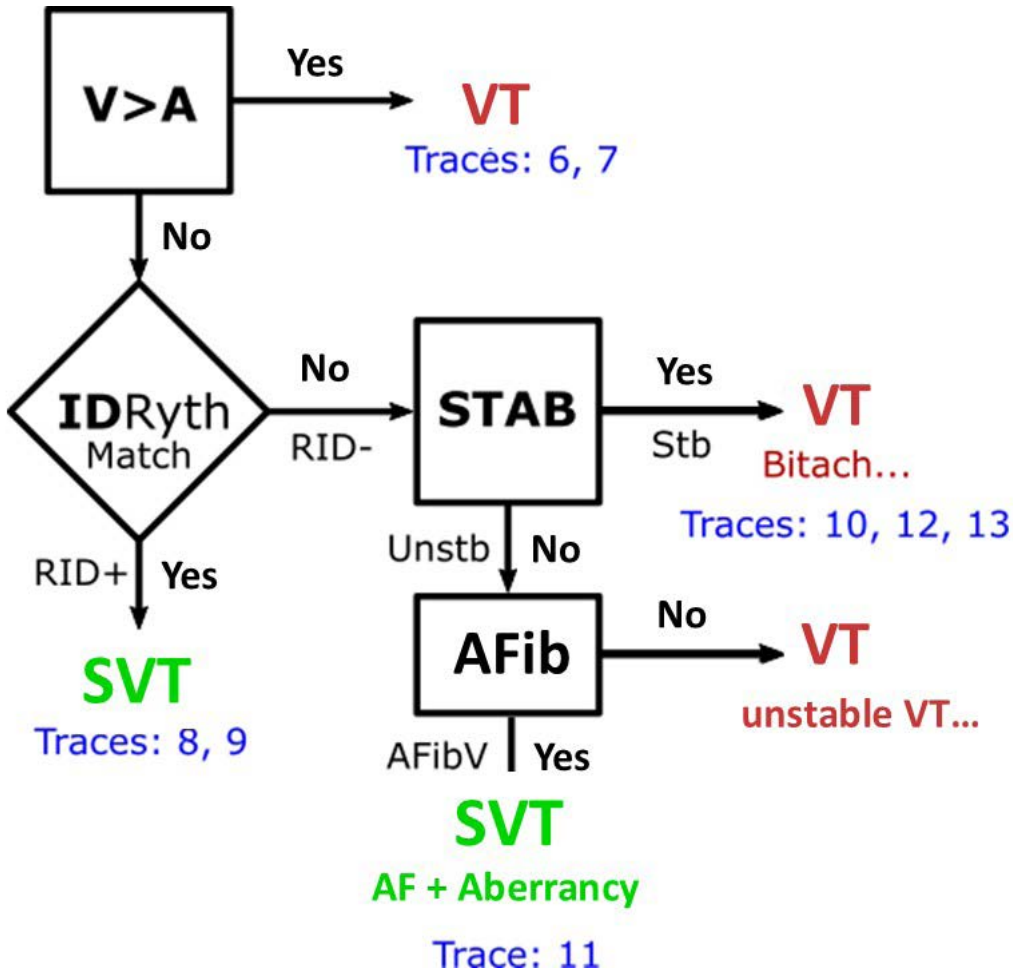
- Boston Scientific VR devices offer two discrimination (enhanced detection) modes: Rhythm ID or Onset/Stability. These two modes cannot be combined.
- **Rhythm ID**: initial discrimination is based solely on morphology. In post-shock, stability alone will be used to discriminate possible AF. NB: post-shock stability cannot be deactivated. See tracings 1 to 5.
- **Onset/stability** this mode is subdivided into ***discrimination of atrial tachyarrhythmias*** (based on the stability criterion) and ***discrimination of sinus tachycardias*** (based on the onset criterion). When both options are selected, you can choose to associate (AND) or dissociate (OR) the discriminants. When they are combined, the arrhythmia will only be treated in the presence of an abrupt onset AND a stable rhythm. When they are dissociated, the arrhythmia is treated in the presence of an abrupt onset OR a stable rhythm. In post-shock, stability alone will be used to discriminate possible AF.. NB: when this mode is selected in 3-zone programming (VT-1/VT/VF), discrimination is only possible in the VT-1 zone.

Dual/triple-chambre algorithms

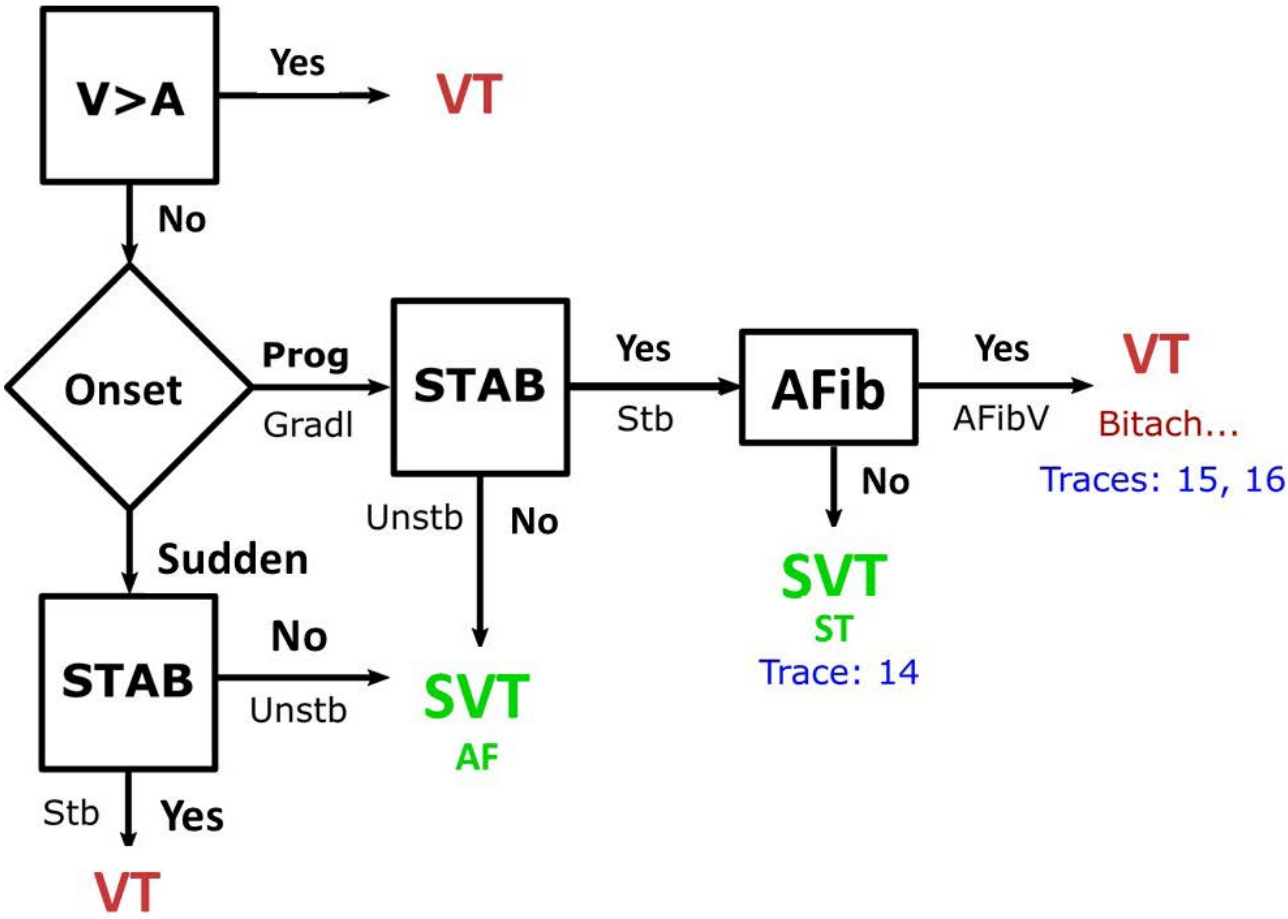
- lBoston Scientific DR and CRT devices offer two modes of discrimination (to improve detection): Rhythm ID or Start/Stability. These two options differ from the options offered in single-chamber models, since they incorporate information from the atrial channel. To access the settings, program Detection Enhancement.
- **Rhythm ID:** This dual-chamber algorithm uses a combination of the following parameters: 1) comparison of A and V rates, 2) Rhythm ID morphology (Rhythm ID), 3) ventricular stability (STAB) and 4) Afib rate threshold (AFib). This is the most efficient discrimination algorithm and should therefore be preferentially applied, even for CRT devices (in which case the Rhythm ID reference should be acquired manually).

Discrimination: Intro

- By going to the Enhanced Detection menu, then Current Rhythm ID settings, you can access the Rhythm ID, Stability and AFib rate threshold settings.
- In the Current Rhythm ID settings menu, you can deactivate discrimination of atrial tachyarrhythmias to restore single-chamber Rhythm ID discrimination (useful in the event of atrial lead failure).
- This dual-chamber algorithm uses a combination of the following parameters: 1) comparison of A and V rates, 2) Rhythm ID morphology (Rhythm ID), 3) ventricular stability (STAB) and 4) Afib rate threshold (AFib). This is the most efficient discrimination algorithm and should therefore be preferentially applied, even for CRT devices (in which case the Rhythm ID reference should be acquired manually).



- **Onset/Stability:** This dual-chamber algorithm uses a combination of the following parameters: 1) comparison of A and V rates, 2) sudden onset (Onset), 3) ventricular stability (STAB) and 4) AFib rate threshold (AFib). It should only be used in the event of Rhythm ID failure.
- By going to the Enhanced Detection menu, then Current Rhythm ID Settings, you can access the V rate > A rate (on/off), onset, stability and AFib rate threshold settings.



- To restore single-chamber operation (in the event of failure of A lead and Rhythm ID failure), the V rate > A rate and AFib rate threshold branches must be deactivated. In this case, remember that discrimination will only apply to the first VT-1 zone of a 3-zone configuration (no discrimination in VT and VF).

1 Single-chamber discrimination, Rhythm ID and a ventricular tachycardia episode

Patient

- 43-year-old male; ischemic cardiomyopathy; implanted with Resonate single-chamber defibrillator

Summary

- discrimination based on Rhythm ID (threshold programmed at 94%)
- episode diagnosed as VT at a rate of 217 beats/minute
- no correlation between tachycardia ventricular electrogram morphology and reference morphology (Rhythm ID correlated: False)
- episode treated with a burst of ATP

EGM layout

1. abrupt onset of a relatively stable tachycardia (rate above 200 beats/minute) with a different morphology on the shock channel compared to the ventricular electrogram in sinus rhythm
2. start of morphology analysis; no correlation (U = uncorrelated) with reference morphology (0%)
3. V-Epsd marker after 8 cycles classified as VT; start of initial duration for VT zone (12 seconds)
4. end of duration; V-detect marker; discrimination (RID-) is in favor of VT; the vector is correlated with the reference vector for fewer than 3 of 10 beats in a rolling window (none of the last 10 ventricular complexes before the end of the duration are correlated).
5. ATP burst
6. effective burst and arrhythmia termination

V-2: 23 févr. 2022 21:55, TV, Fréquence V : 227 min^{-1}

Détail

TV Début événem.

Fréq. V moy.	227 min^{-1}
Détection	ID de Rythme
Référence	23 févr. 2022 21:11
Seuil du RhythmMatch™	94 %

Lors de la Détect-V

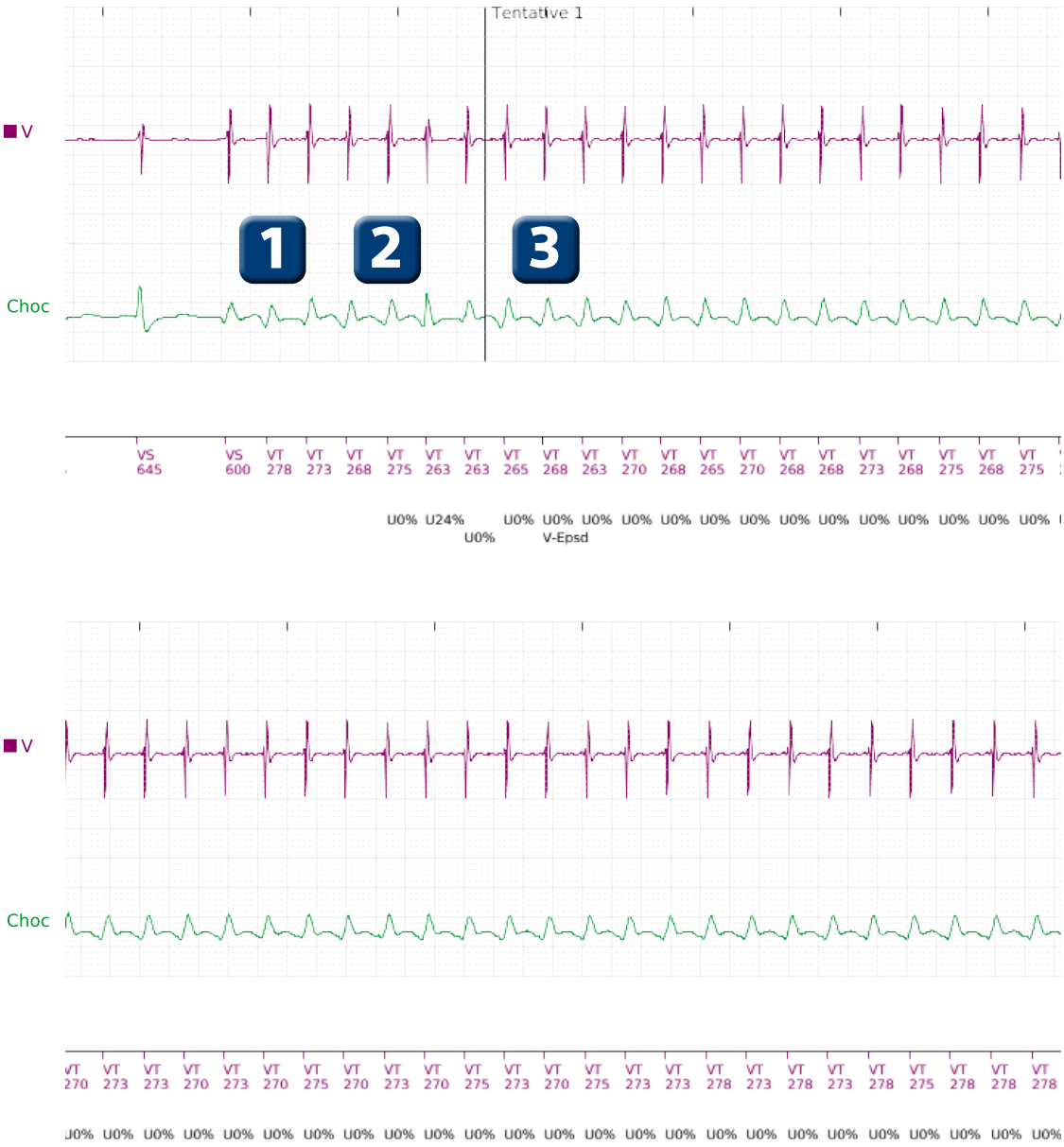
Fréq. V moy.	217 min^{-1}
Zone de fréquence	TV
RhythmID corrélé	Faux
RhythmMatch™	0 %
DFS satisfaite	(Faux, arrêt)
Durée limite ATP	Faux

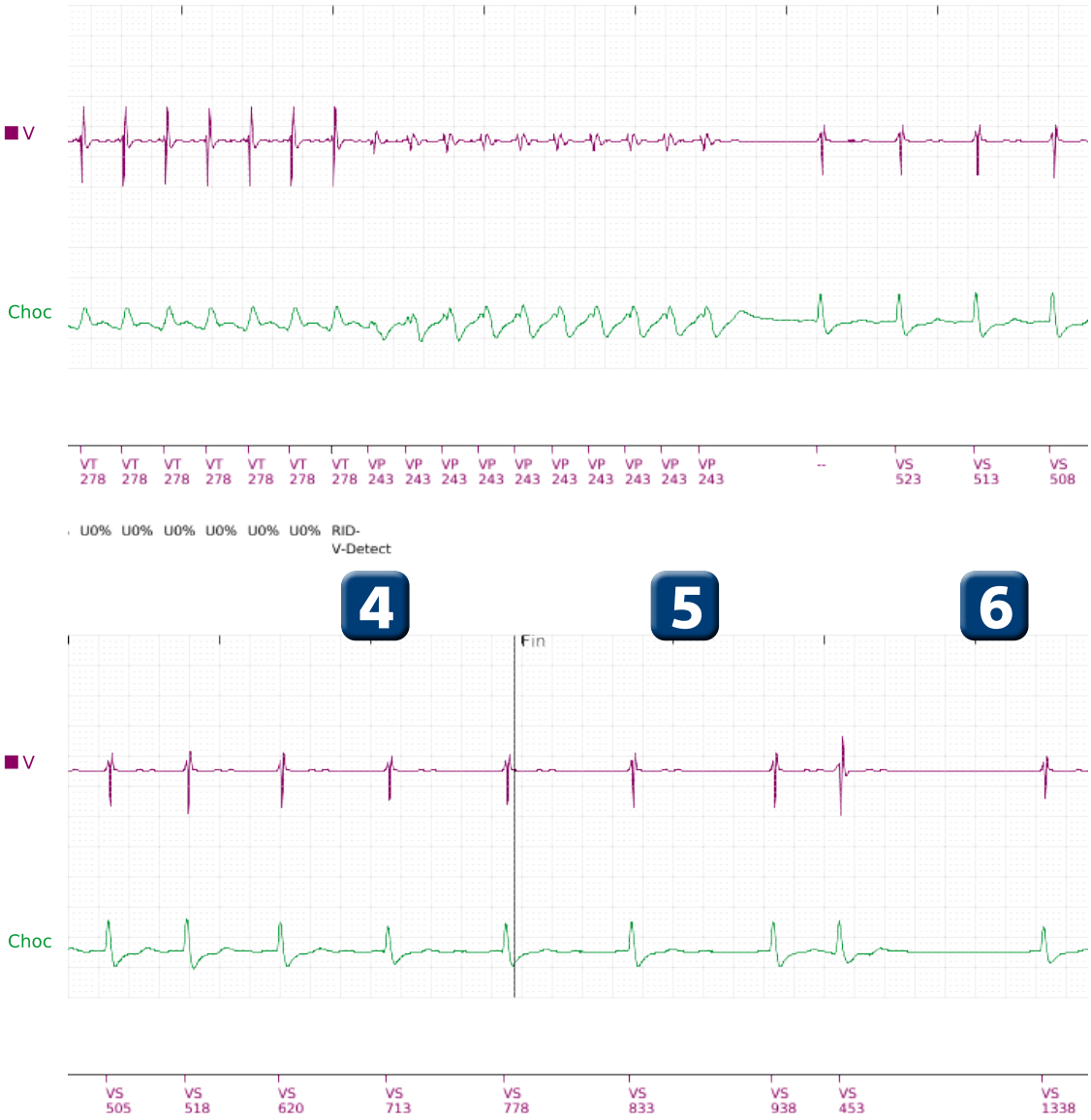
Tentative 1, Salve ATP V

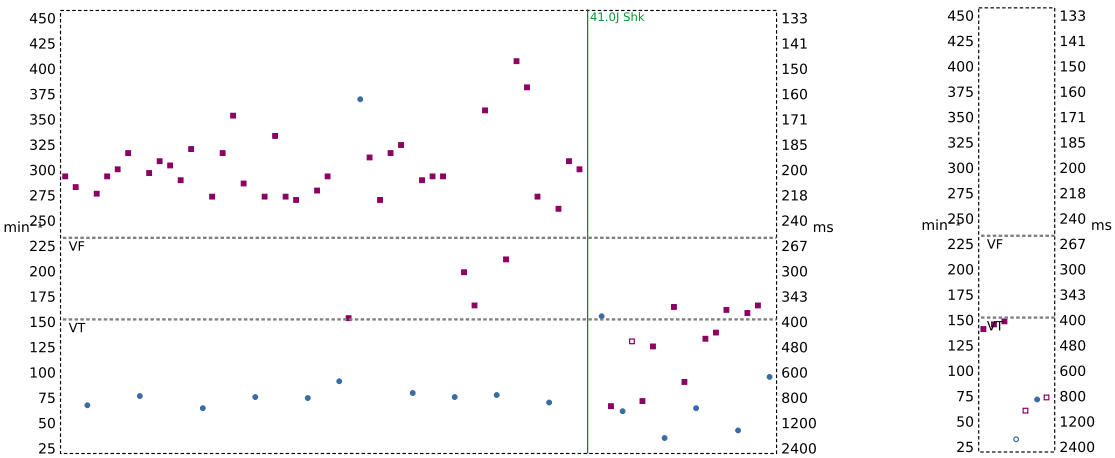
Temps écoulé	00:00:12
Informations ATP	
Nombre de salves	1

Fin de l'événement 00:00:26

EGM affiché à 25 mm par seconde




V
Choc
VT 278 VT 278 VT 278 VT 278 VT 278 VT 278 VT 278 VP 243 VP 243 VP 243 VP 243 VP 243 VP 243 VP 243 VP 243 VP 243 -- VS 523 VS 513 VS 508
U0% U0% U0% U0% U0% U0% RID-
V-Detect
4
5
6
Fin
V
Choc
VS 505 VS 518 VS 620 VS 713 VS 778 VS 833 VS 938 VS 453 VS 1338

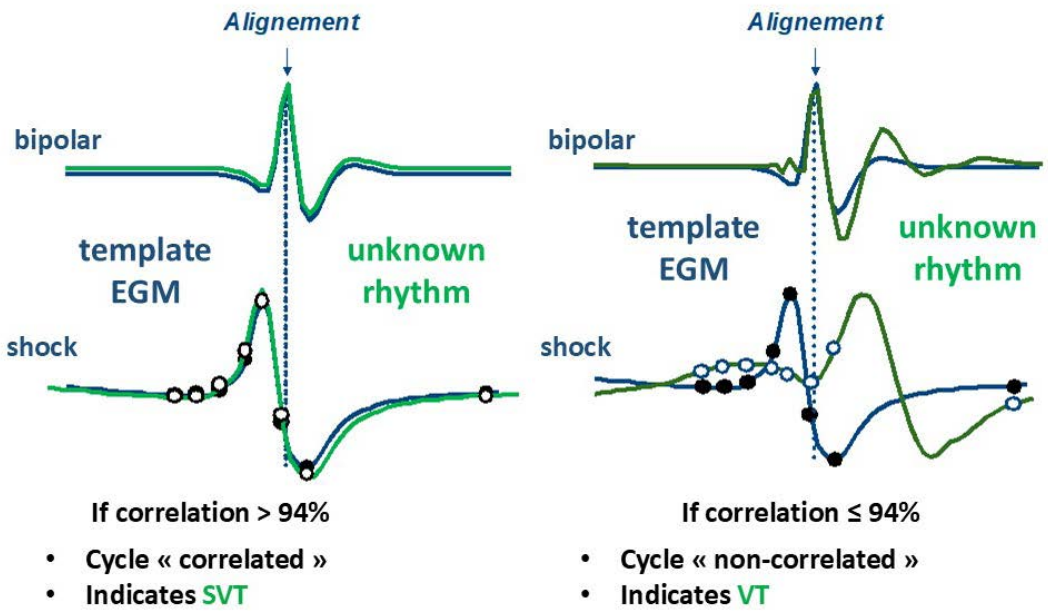

41.0J Shk
VF
VT
min
ms
450 425 400 375 350 325 300 275 250 225 200 175 150 125 100 75 50 25
133 141 150 160 171 185 200 218 240 267 300 343 400 480 600 800 1200 2400

Points to remember

- the initial detection of an arrhythmia episode is based on rate and duration criteria; the concept of heart rate is essential, but too simplistic to differentiate between ventricular and supra-ventricular arrhythmias; implementation of a heart rate criterion on its own carries a sensitivity of 100%, but limited specificity of no more than 60%; improving specificity therefore relies on discrimination, which is the ability of a defibrillator to identify a supra-ventricular or ventricular origin for an episode of tachycardia, based on the characteristics of the detected arrhythmia.
- discrimination algorithms should only be programmed in patients likely to present with conducted supraventricular tachycardia, and should be deactivated in patients with complete and permanent atrioventricular block where any spontaneous rapid rhythm can only be of ventricular origin
- if all discrimination criteria are disabled, therapy is delivered regardless of the origin of the tachycardia
- for Boston ScientificTM devices, the discrimination algorithms are only functional in VT zones (VT and/or VT-1); in the VF zone, a safety first approach prevails and the detection by the defibrillator of a high ventricular rate entering the «VF detected» zone triggers the programmed therapies, without the episode being «filtered» by discrimination algorithms
- the detection of an arrhythmia episode, whether supraventricular or ventricular, triggers the storage of an endocardial electrogram that is accessible during defibrillator interrogation; this enables critical analysis of the defibrillator's diagnostic conclusions and possible reprogramming in the event of tachycardia misclassification
- 2 different «packages» are available on Boston ScientificTM defibrillators to enable discrimination of arrhythmia origin: the Rhythm ID algorithm and the Onset/Stability algorithm; the Rhythm ID discrimination option is available in isolation (only discriminant used) on a single-chamber defibrillator and is based on a comparison

between ventricular vectors in tachycardia and a reference vector recorded outside a tachycardia episode.

- the performance of a discrimination algorithm is assessed based on its sensitivity (ability to correctly diagnose a VT; this should be as close as possible to 100%; a sensitivity of 95% means that 5% of VTs will be incorrectly diagnosed as SVT) and specificity (ability to inhibit therapies for an episode of SVT; this should be as high as possible without altering sensitivity).
- in this example of appropriate therapy for VT, the difference in morphology between sinus rhythm and tachycardia was obvious; the nominal threshold value of 94% was programmed and all tachycardia vectors were deemed uncorrelated, explaining the diagnosis of VT and the decision to treat



Operating principle of Rhythm-ID discriminantion: comparison between ventricular vectors in tachycardia and a reference vector; the bipolar sensing EGM enables alignment (localization of QRS peaks), and the comparison is made on the shock channel (decomposition of the QRS complex into 8 equidistant points).

2 Single-chamber discrimination, Rhythm ID and an atrial fibrillation episode

Patient

- 59-year-old male; implanted with a Resonate single-chamber defibrillator for hypertrophic cardiomyopathy;

Summary

- discrimination based on Rhythm ID (threshold programmed at 94%)
- episode of tachycardia at 167 beats/minute with inhibition of therapies (Rhythm ID correlated: True)

EGM layout

1. irregular tachycardia with ventricular electrograms appearing fine on the shock channel; alternation between cycles classified as VT-1 and VS; correlation (C = correlated) between all cycles and the reference morphology (percentage above the programmed threshold of 94%).
2. end-of-episode marker V-EpsdEnd (corresponding to the previous episode not visualized on this plot), criterion 8/10 was not fulfilled.
3. V-Epsd marker after 8 cycles out of 10 classified as VT1
4. end of duration (V-duration marker); discrimination (RID+) favors SVT; for at least 3 beats/10 (rolling window), the vector during tachycardia is correlated with the reference vector (the last 10 ventricular complexes before the end of duration are correlated).

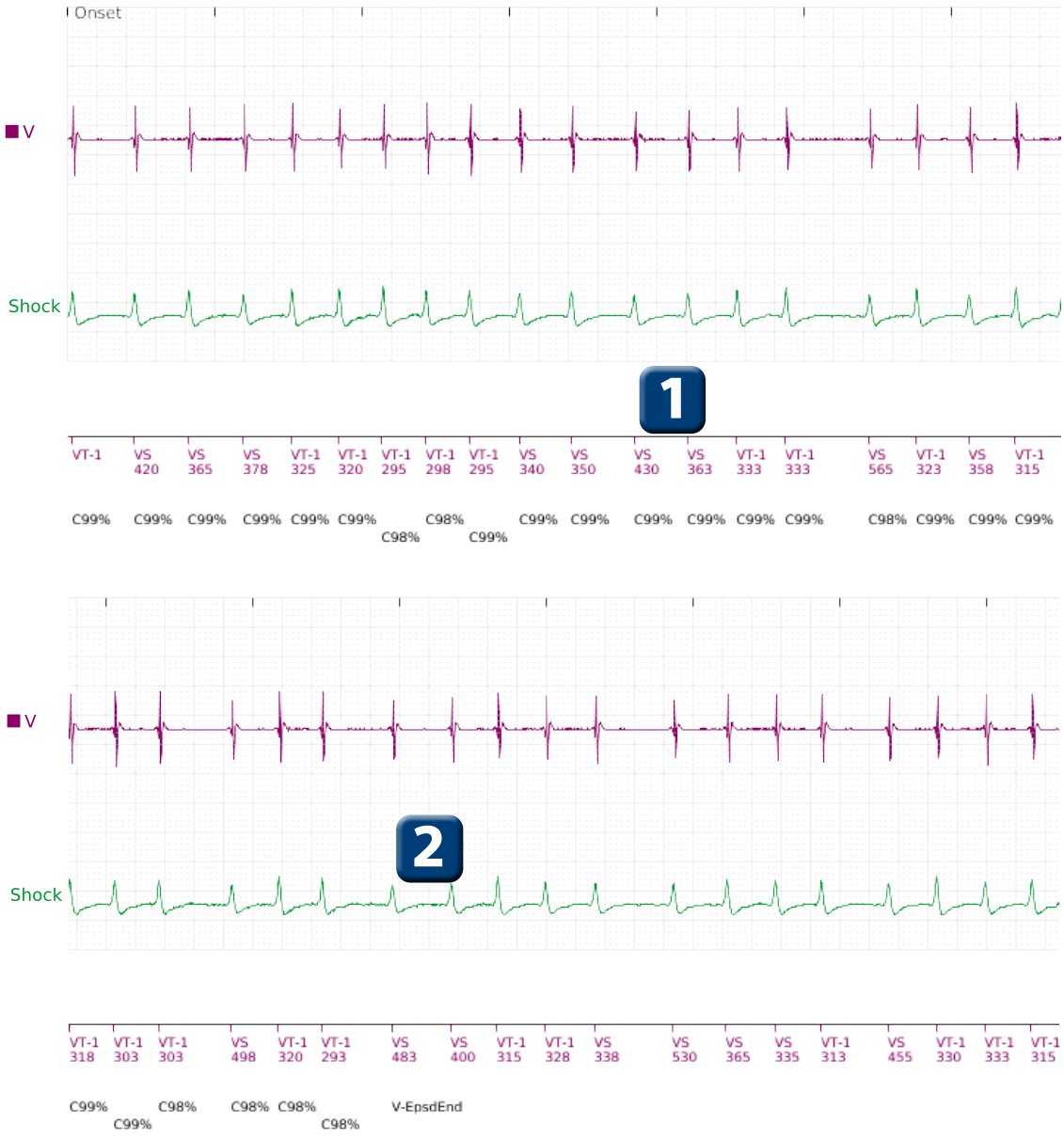
V-22: 20 Sep 2022 18:25, VT-1, V Rate: 167 min^{-1}

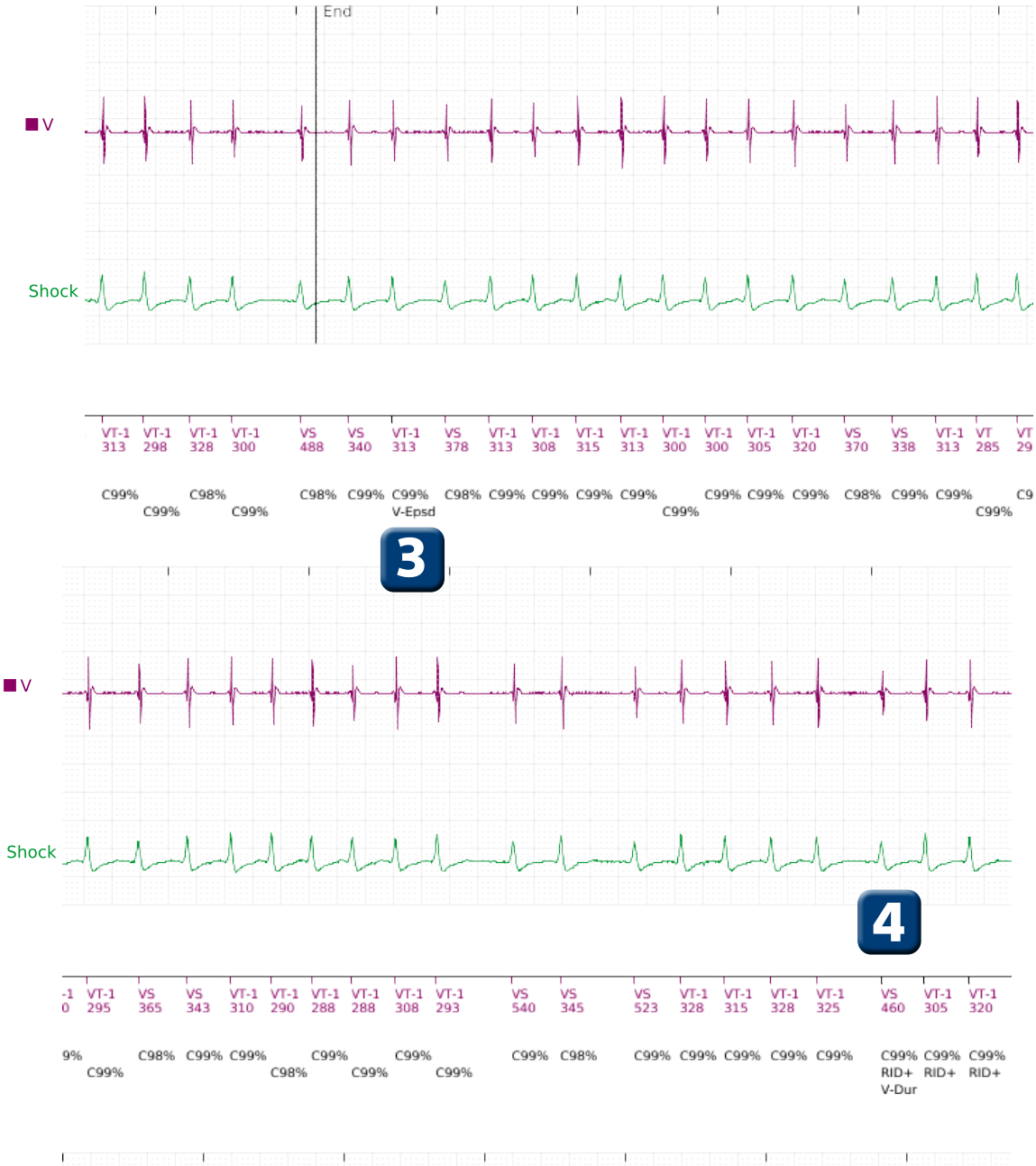
Detail

VT-1 Event Onset

Avg V Rate	167 min^{-1}	
Detection	Rhythm ID	
Template	20 Sep 2022 14:13	
RhythmMatch™ Threshold	94 %	
At Inhibit RhythmMatch™	99 %	
Event Ended		00:00:23

EGM displayed at 25mm per second

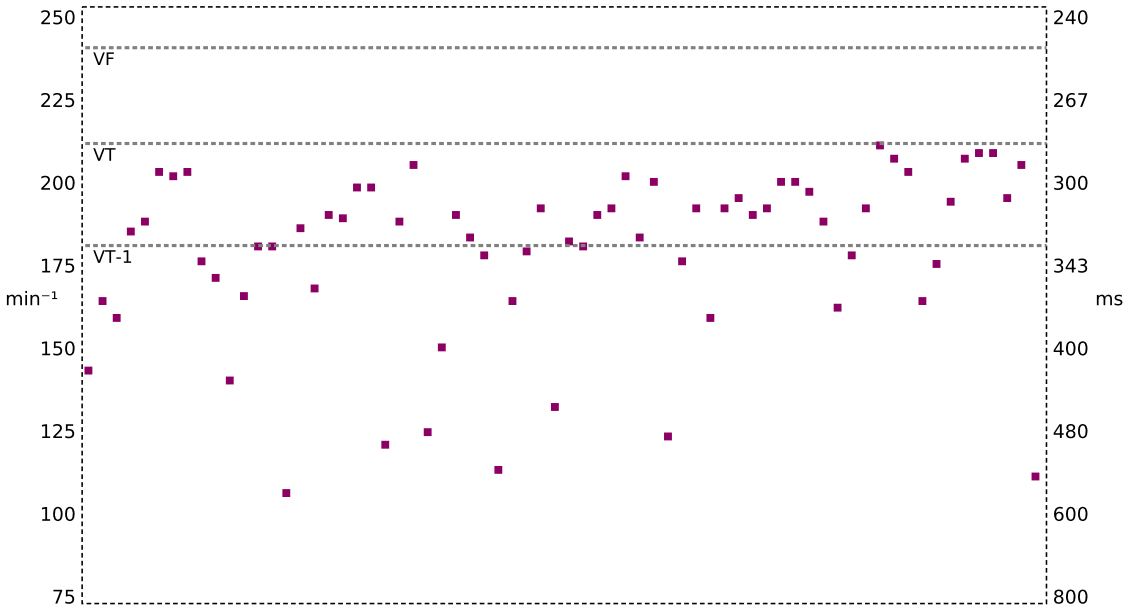



End
V
Shock
VT-1 313 C99%
VT-1 298 C99%
VT-1 328 C98%
VT-1 300 C99%
VS 488 C98%
VS 340 C99%
VT-1 313 C99% V-Epsd
VS 378 C98%
VT-1 313 C99%
VT-1 308 C99%
VT-1 315 C99%
VT-1 313 C99%
VT-1 300 C99%
VT-1 300 C99%
VT-1 305 C99%
VT-1 320 C99%
VS 370 C98%
VS 338 C99%
VT-1 313 C99%
VT 285 C99%
3
V
Shock
VT-1 295 C99%
VS 365 C98%
VS 343 C99%
VT-1 310 C99%
VT-1 290 C98%
VT-1 288 C99%
VT-1 288 C99%
VT-1 308 C99%
VT-1 293 C99%
VS 540 C99%
VS 345 C98%
VS 523 C99%
VT-1 328 C99%
VT-1 315 C99%
VT-1 328 C99%
VT-1 325 C99%
VS 460 C99% RID+ V-Dur
VT-1 305 C99% RID+
VT-1 320 C99% RID+
4

Points to remember

- Rhythm ID discrimination is available on single, dual and triple-chamber defibrillators and is based on the comparison, at initial detection, between vectors during tachycardia and a reference vector recorded in the absence of tachycardia.
- the bipolar sensed EGM enables alignment (localization of QRS peaks), with comparison then being made on the shock channel (decomposition of the QRS complex into 8 equidistant points); use of the shock channel enables a broader and more accurate analysis of a signal than an analysis based solely on the bipolar sensing channel
- for each tachycardia cycle, a percentage similarity is determined and compared to a programmable threshold; if the percentage equals or exceeds the threshold, the ventricular electrogram is deemed correlated (favoring SVT), otherwise it is deemed uncorrelated (favoring VT).
- if at least 3 out of 10 ventricular cycles are correlated (rolling window of 10 cycles), the tachycardia is considered supraventricular and therapies are inhibited (indicated as RID+)
- if fewer than 3 out of 10 ventricular cycles are correlated, the tachycardia is considered ventricular and therapies are delivered (indicated as RID-).
- a cycle classified in the VF zone is always counted as uncorrelated, even if its correlation seems high

- programming of the RhythmMatch threshold parameter adjusts the correlation threshold to determine whether the cycle analyzed is correlated with its normal sinus rhythm template; this threshold is programmable on new platforms between 70% and 96%, with a nominal value of 94%; on older platforms this threshold was non-programmable and fixed at 94%.
- in this patient, the nominal threshold value was programmed (94%); all tachycardia vectors were judged to be correlated, explaining the diagnosis of SVT and the decision to inhibit therapies



The interval plot corresponding to this episode is highly suggestive of atrial fibrillation, with great variability in ventricular cycles (cycles ranging from 100 to 210 beats/minute).

3 Single-chamber discrimination, Rhythm ID and sinus tachycardia

Patient

- 59-year-old male; ischemic cardiomyopathy; implanted with a Resonate single-chamber defibrillator

Summary

- discrimination based on Rhythm ID (threshold programmed at 94%)
- episode of tachycardia at 150 beats/minute with inhibition of therapies (Rhythm ID correlated: True)

EGM layout

1. regular tachycardia with narrow ventricular complexes on the shock channel; progressive acceleration with cycles classified as VS then VT-1; correlation (C = correlated) of all cycles with the reference morphology (above the programmed threshold of 94%).
2. end-of-episode marker V-EpsdEnd (corresponding to the previous episode that is not visualized on this plot), criterion 8/10 having not been satisfied.
3. V-Epsd marker after 8 cycles classified VT-1 following the end-of-episode marker
4. end of duration; V-dur marker; rate slows with cycles classified as VS; all ventricular complexes remain correlated

V-149: 18 Dec 2022 09:37, VT-1, V Rate: 148 min^{-1}

Detail

VT-1 Event Onset

Avg V Rate	148 min^{-1}
Detection	Rhythm ID
Template	18 Dec 2022 09:26
RhythmMatch™ Threshold	94 %

At V-Detect

Avg V Rate	150 min^{-1}
Rate Zone	VT-1
RhythmID Correlated	True
RhythmMatch™	98 %
SRD Met	(False, Off)
ATP Timeout	False

Attempt 1, Non Therapy V

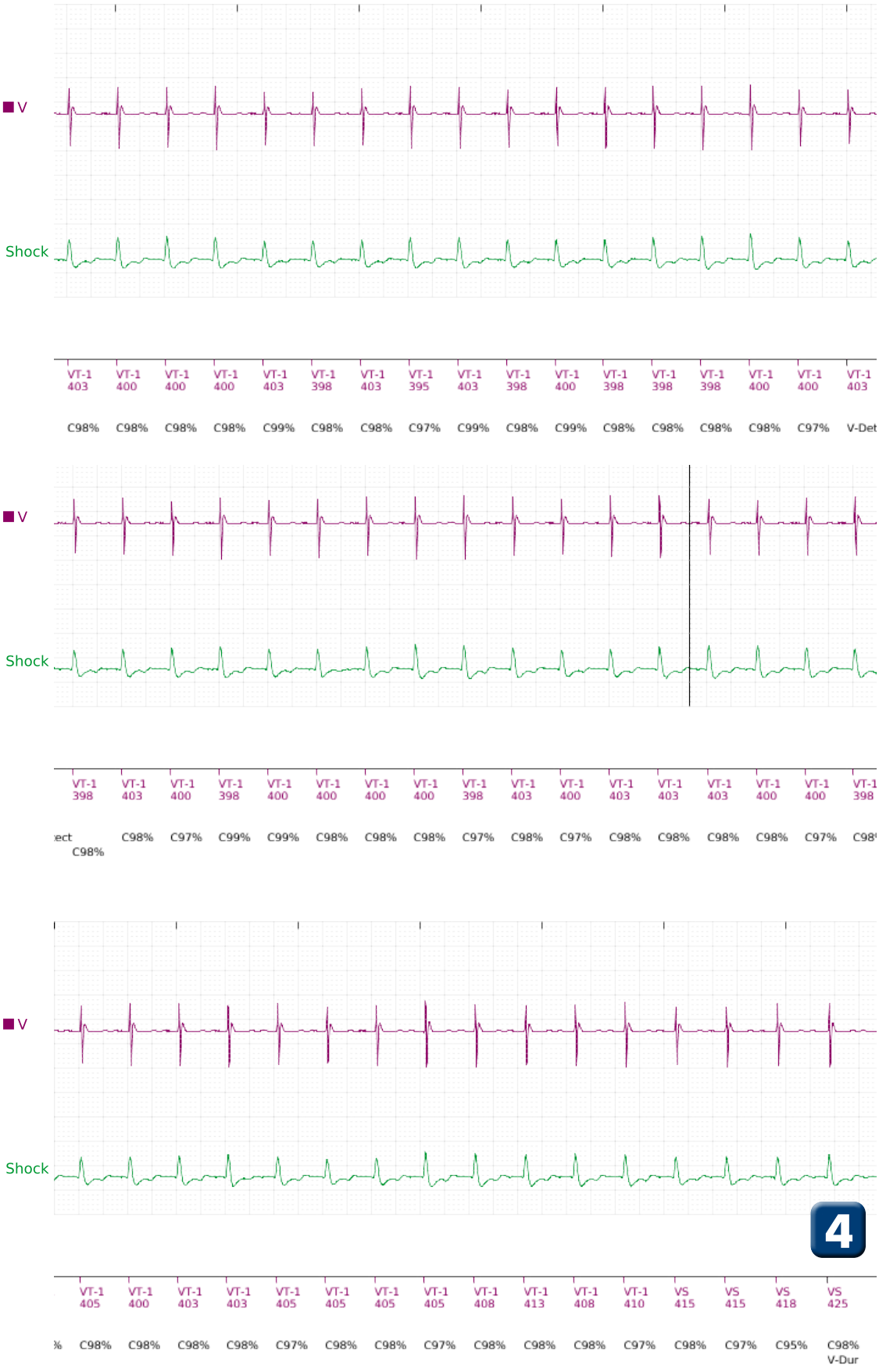
Elapsed Time	00:00:10

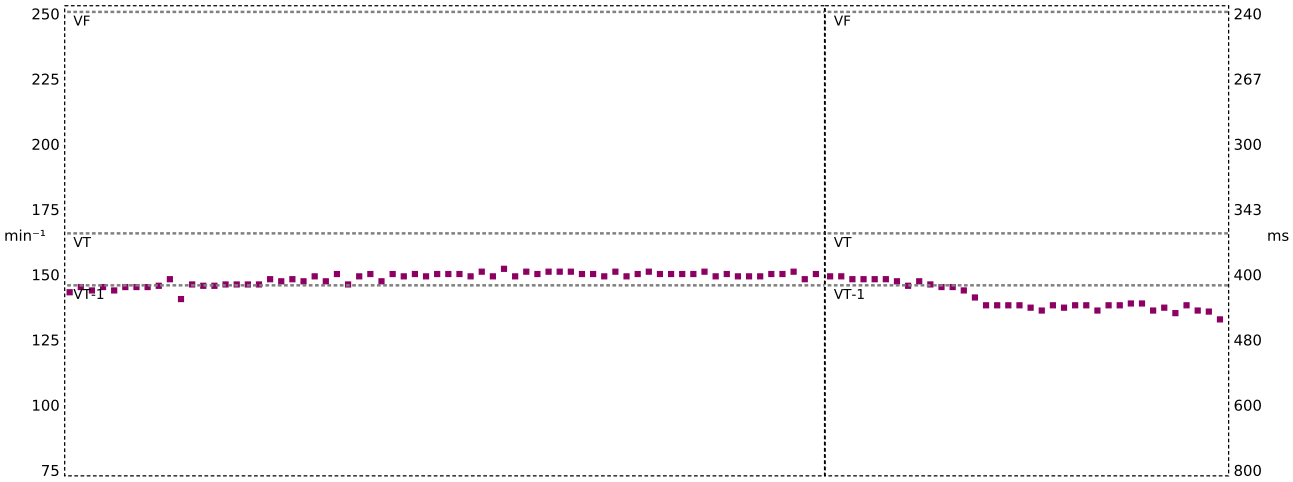
Attempt Information

Tachy therapy is programmed off.

Event Ended 00:00:34

EGM displayed at 25mm per second


V
Shock
VT-1 403 VT-1 400 VT-1 400 VT-1 400 VT-1 403 VT-1 398 VT-1 403 VT-1 395 VT-1 403 VT-1 398 VT-1 400 VT-1 398 VT-1 398 VT-1 398 VT-1 400 VT-1 400 VT-1 403
C98% C98% C98% C98% C99% C98% C98% C97% C99% C98% C99% C98% C98% C98% C98% C97% V-Det
V
Shock
VT-1 398 VT-1 403 VT-1 400 VT-1 398 VT-1 400 VT-1 400 VT-1 400 VT-1 400 VT-1 398 VT-1 403 VT-1 400 VT-1 403 VT-1 403 VT-1 403 VT-1 400 VT-1 400 VT-1 398
ect C98% C98% C97% C99% C99% C98% C98% C98% C97% C98% C97% C98% C98% C98% C98% C97%
V
Shock
4
VT-1 405 VT-1 400 VT-1 403 VT-1 403 VT-1 405 VT-1 405 VT-1 405 VT-1 405 VT-1 408 VT-1 413 VT-1 408 VT-1 410 VS 415 VS 415 VS 418 VS 425
% C98% C98% C98% C98% C97% C98% C98% C97% C98% C98% C98% C97% C98% C97% C95% C98% V-Dur



The interval plot corresponding to this episode is highly suggestive of sinus tachycardia, with progressive acceleration of ventricular cycles followed by gradual deceleration.

Points to remember

- Morphology discrimination is based on comparison with a reference ventricular electrogram, which can be acquired in real time during interrogation with a programmer, and then automatically updated by the device.
- there are two methods of automatic acquisition of a reference template by the device: passive and active
- for the passive method, the device searches for spontaneous ventricular activity every 2 hours to collect the reference template, without modifying any programming parameters
- in contrast, with the active method, the search for spontaneous ventricular activity is performed every 28 hours, with temporary modification of pacing parameters (pacing mode that encourages spontaneous ventricular activity with a slower pacing rate and longer AV delay); the active method is preferred in patients with a high ventricular pacing percentage (in totally dependent patients, no discrimination should be programmed)
- during follow-up interrogations, it is possible to check that the percentage match between spontaneous ventricular activity observed during the consultation and the reference ventriculogram is high (above the programmed threshold and as close as possible to 100%).
- in this patient, the nominal threshold value was programmed (94%); all tachycardia vectors were judged to be correlated, explaining the diagnosis of SVT and the decision to inhibit therapies
- the patients who benefit most from discrimination are those where the heart rate ranges of ventricular tachycardia and supraventricular tachycardia overlap (patients with slow VT, patients likely to present with rapid AF, young patients with rapid sinus tachycardia on exertion)

4 Single-chamber discrimination, Rhythm ID and correlation percentage

Patient

- 78-year-old male; implanted with an Incepta single-chamber defibrillator for ischemic cardiomyopathy;

Summary

- discrimination based on Rhythm ID (threshold programmed at 94%)
- tachycardia at 124 beats/minute
- initially untreated episode (Rhythm ID correlated: True)
- subsequent treated episode with exhaustion of all available treatments for the VT zone

EGM layout

1 regular tachycardia with ventricular elecgtrograms appearing fnarrow on the shock channel; progressive acceleration with cycles classified as VS then VT-1; initially, there is correlation (C = correlated) of all cycles with reference morphology (percentage above the programmed threshold of 94%).

2 end of duration for VT-1 zone (no therapy programmed in this zone)

3 acceleration of the tachycardia with cycles classified as VT; discrimination (RID+) is in favor of SVT; for at least 3/10 beats (rolling window), the vector is correlated with the reference vector (the last 10 ventricular complexes are correlated)

4 V-detect marker; discrimination (RID-) is in favor of VT; the vector correlates with the reference vector for fewer than 3 beats/10 in a rolling window (only 2 of the last 10 ventricular complexes have a percentage above the programmed threshold of 94%).

5 burst delivered (inappropriate)

6 following this burst, redetection of a VT episode; no discrimination based on morphology analysis is performed after therapy (ATP or shock) has been delivered

7 all therapies programmed in the VT zone are delivered

V-2432: 02 Apr 2018 10:26, VT-1, V Rate: 122 min^{-1}

Detail

VT-1 Event Onset

Avg V Rate	122 min^{-1}
Detection	Rhythm ID
Template	02 Apr 2018 10:03
RhythmMatch™ Threshold	94 %

At V-Detect

Avg V Rate	124 min^{-1}
Rate Zone	VT-1
RhythmID Correlated	True
RhythmMatch™	98 %
SRD Met	(False, Off)
ATP Timeout	False

At Inhibit

RhythmID Correlated	True

At V-Detect

Avg V Rate	145 min^{-1}
Rate Zone	VT
SRD Met	(False, Off)
ATP Timeout	False

At V-Detect

Avg V Rate	149 min^{-1}
Rate Zone	VT
ATP Timeout	False

At V-Detect

Avg V Rate	147 min^{-1}
Rate Zone	VT
ATP Timeout	False

At V-Detect

Avg V Rate	144 min^{-1}
Rate Zone	VT
Stability	(98 ms, Off)
SRD Met	False
ATP Timeout	False

At V-Detect

Avg V Rate	150 min^{-1}
Rate Zone	VT
Stability	(83 ms, Off)
SRD Met	False
ATP Timeout	False

At V-Detect

Avg V Rate	150 min^{-1}
Rate Zone	VT
Stability	(30 ms, Off)
SRD Met	False
ATP Timeout	False

At V-Detect

Avg V Rate	152 min^{-1}
Rate Zone	VT
Stability	(43 ms, Off)
SRD Met	False
ATP Timeout	False

At V-Detect

Avg V Rate	147 min^{-1}
Rate Zone	VT
Stability	(53 ms, Off)
SRD Met	False
ATP Timeout	False

At V-Detect

Avg V Rate	151 min^{-1}
Rate Zone	VT
Stability	(22 ms, Off)
SRD Met	False
ATP Timeout	False

Event Ended 00:10:12

Attempt 1, Non Therapy V

Elapsed Time	00:00:08

Attempt Information

Tachy therapy is programmed off.

Attempt 2, Burst V ATP

Elapsed Time	00:02:43

Inhibited Attempt

ATP Information

Number of Bursts	3

Attempt 3, Ramp V ATP

Elapsed Time	00:03:06

ATP Information

Number of Bursts	3

Attempt 4, 11 J V Shock

Elapsed Time	00:03:31

Shock Information

Charge Time	2.0 s
Lead Impedance	63 Ω
Lead Polarity	Initial

Attempt 5, 41 J V Shock

Elapsed Time	00:03:40

Shock Information

Charge Time	9.5 s
Lead Impedance	65 Ω
Lead Polarity	Initial

Attempt 6, 41 J Max V Shock

Elapsed Time	00:03:59

Shock Information

Charge Time	8.1 s
Lead Impedance	65 Ω
Lead Polarity	Initial

Attempt 7, 41 J Max V Shock

Elapsed Time	00:04:13

Shock Information

Charge Time	8.2 s
Lead Impedance	65 Ω
Lead Polarity	Initial

Attempt 8, 41 J Max V Shock

Elapsed Time	00:04:29

Shock Information

Charge Time	8.2 s
Lead Impedance	67 Ω
Lead Polarity	Initial

Attempt 9, 41 J Max V Shock

Elapsed Time	00:04:45

Shock Information

Charge Time	8.3 s
Lead Impedance	70 Ω
Lead Polarity	Reversed

Attempt 10, Non Therapy V

Elapsed Time	00:04:60

Attempt Information

All programmed therapy has been delivered.


Onset
Attempt 1
V
Shock
1
VS
VS 513
VS 505
VS 505
VS 505
VS 505
VS 503
VT-1 498
VT-1 500
VT-1 493
VT-1 495
VT-1 498
VT-1 495
C98%
C99%
C98%
V
Shock
VT-1 490
VT-1 488
VT-1 493
VT-1 490
VT-1 488
VT-1 490
VT-1 483
VT-1 488
VT-1 488
VT-1 485
VT-1 480
VT-1 485
VT-1 483
VT-1 480
C98%
C97% V-Epsd
C98%
C98%
C98%
C98%
C96%
C98%
C98%
C97%
C97%
C98%
V-Detect
V
Shock
VT-1 480
VT-1 475
VT-1 480
VT-1 485
VT-1 480
VT-1 475
VT-1 478
VT-1 478
VT-1 478
VT-1 480
VT-1 473
VT-1 478
VT-1 475
VT-1 475
C97%
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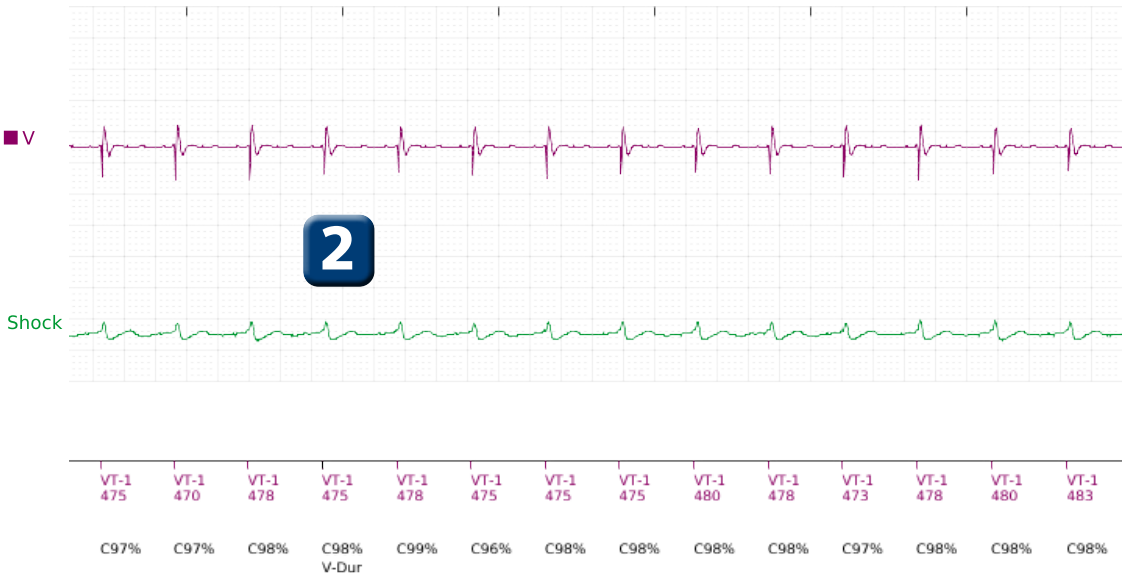
V
2
Shock
VT-1 475
VT-1 470
VT-1 478
VT-1 475
VT-1 478
VT-1 475
VT-1 475
VT-1 475
VT-1 480
VT-1 478
VT-1 473
VT-1 478
VT-1 480
VT-1 483
C97%
C97%
C98%
C98% V-Dur
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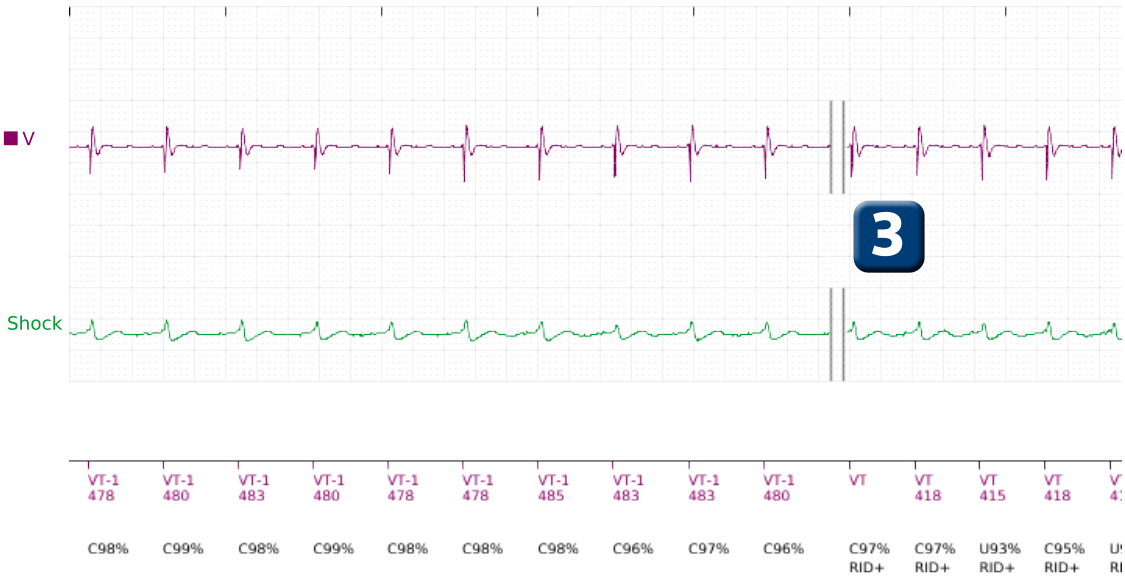
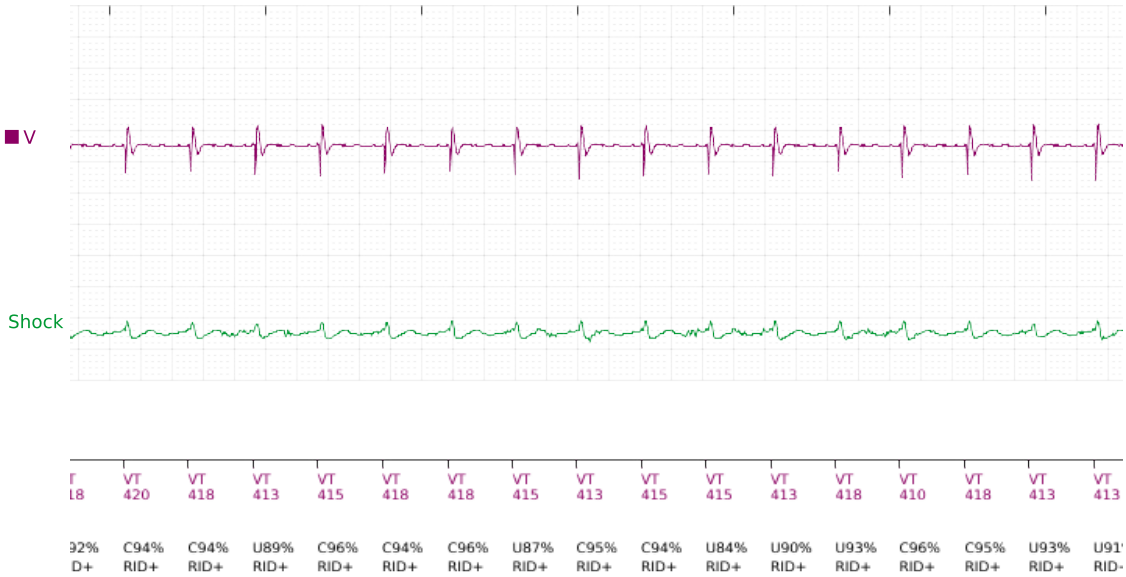
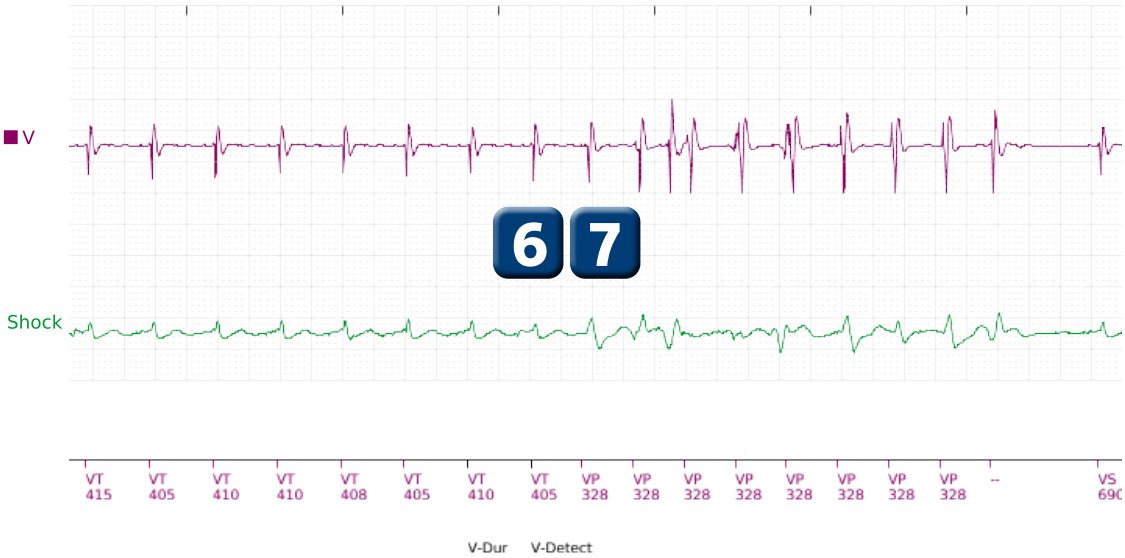
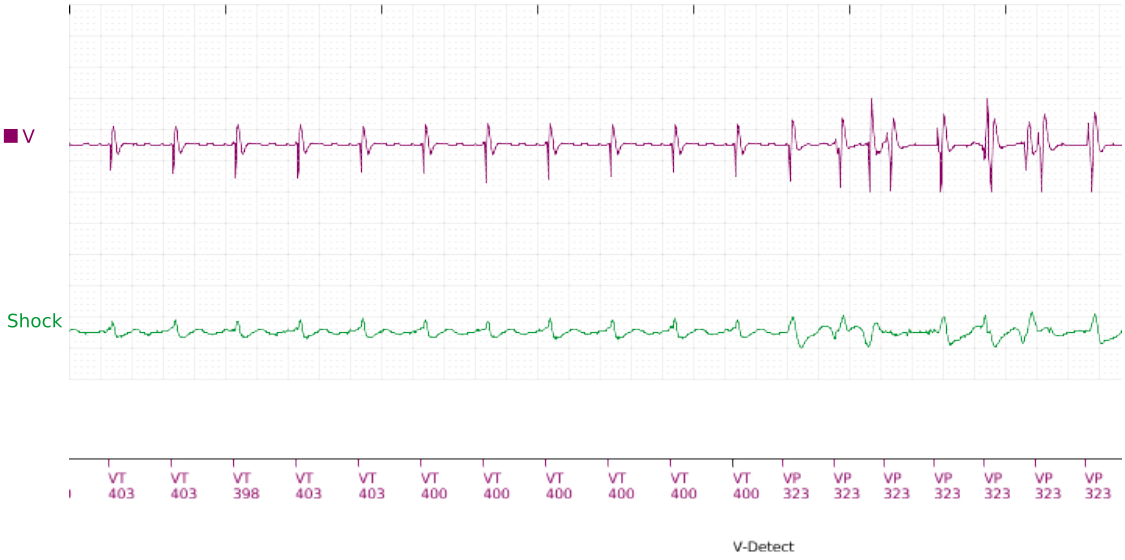

V
3
Shock
VT-1 478
VT-1 480
VT-1 483
VT-1 480
VT-1 478
VT-1 478
VT-1 485
VT-1 483
VT-1 483
VT-1 480
VT
VT 418
VT 415
VT 418
C98%
C99%
C98%
C99%
C98%
C98%
C98%
C96%
C97%
C96%
C97% RID+
C97% RID+
U93% RID+
C95% RID+

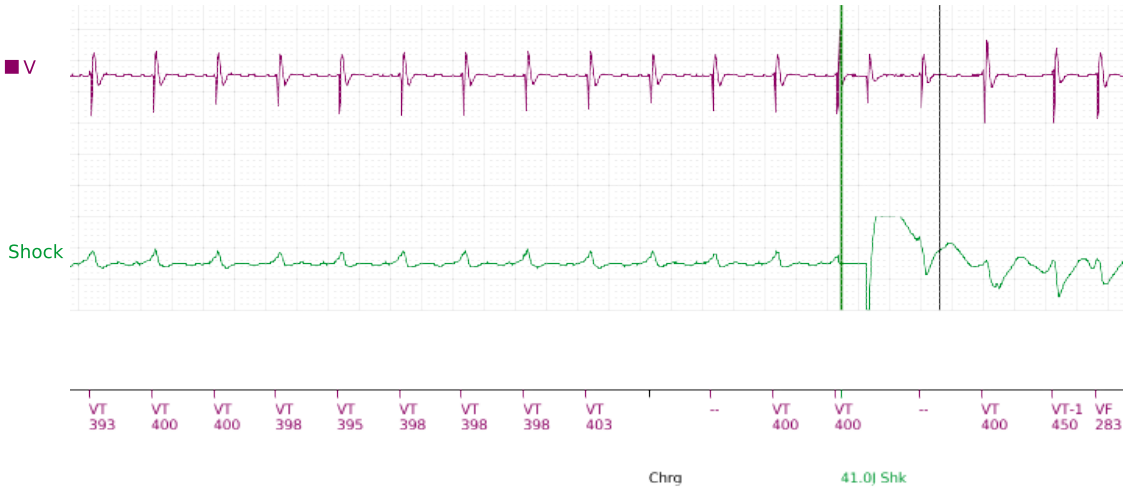

V
Shock
VT 420 VT 418 VT 413 VT 415 VT 418 VT 418 VT 415 VT 413 VT 415 VT 415 VT 413 VT 418 VT 410 VT 418 VT 413 VT 413
C94% RID+ C94% RID+ U89% RID+ C96% RID+ C94% RID+ C96% RID+ U87% RID+ C95% RID+ C94% RID+ U84% RID+ U90% RID+ U93% RID+ C96% RID+ C95% RID+ U93% RID+

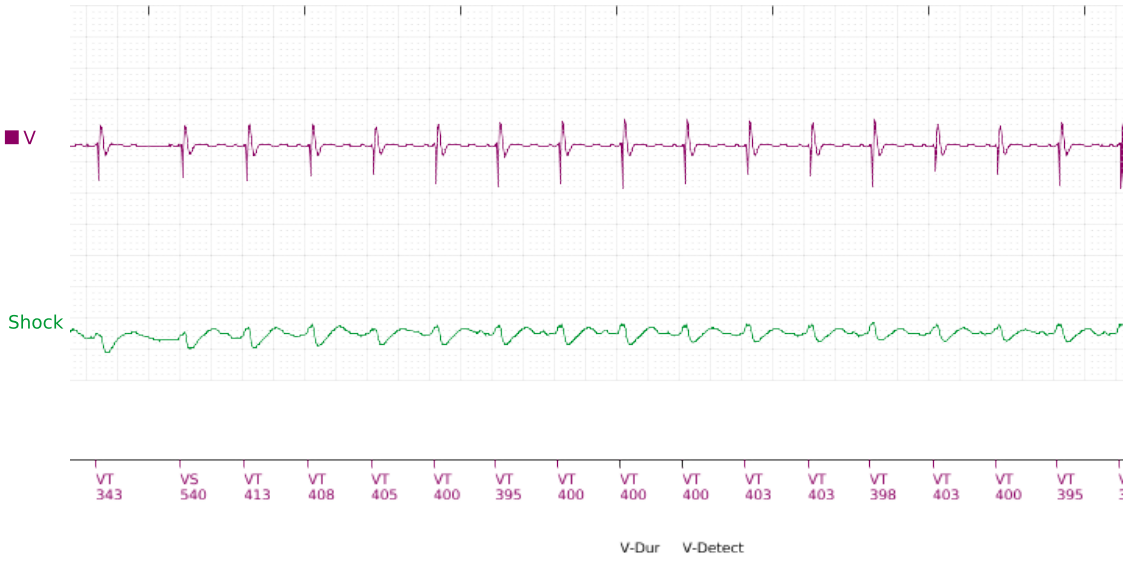

V
4 5
Shock
VT 415 VT 410 VT 418 VT 413 VP 333 VP 333 VP 333 VP 333 VP 333 VP 333 VP 333 VP 333 -- VF 218 VT-1 440 VF 273 VS 668 VT 413
U93% RID+ U93% RID+ U92% RID+ RID- V-Detect

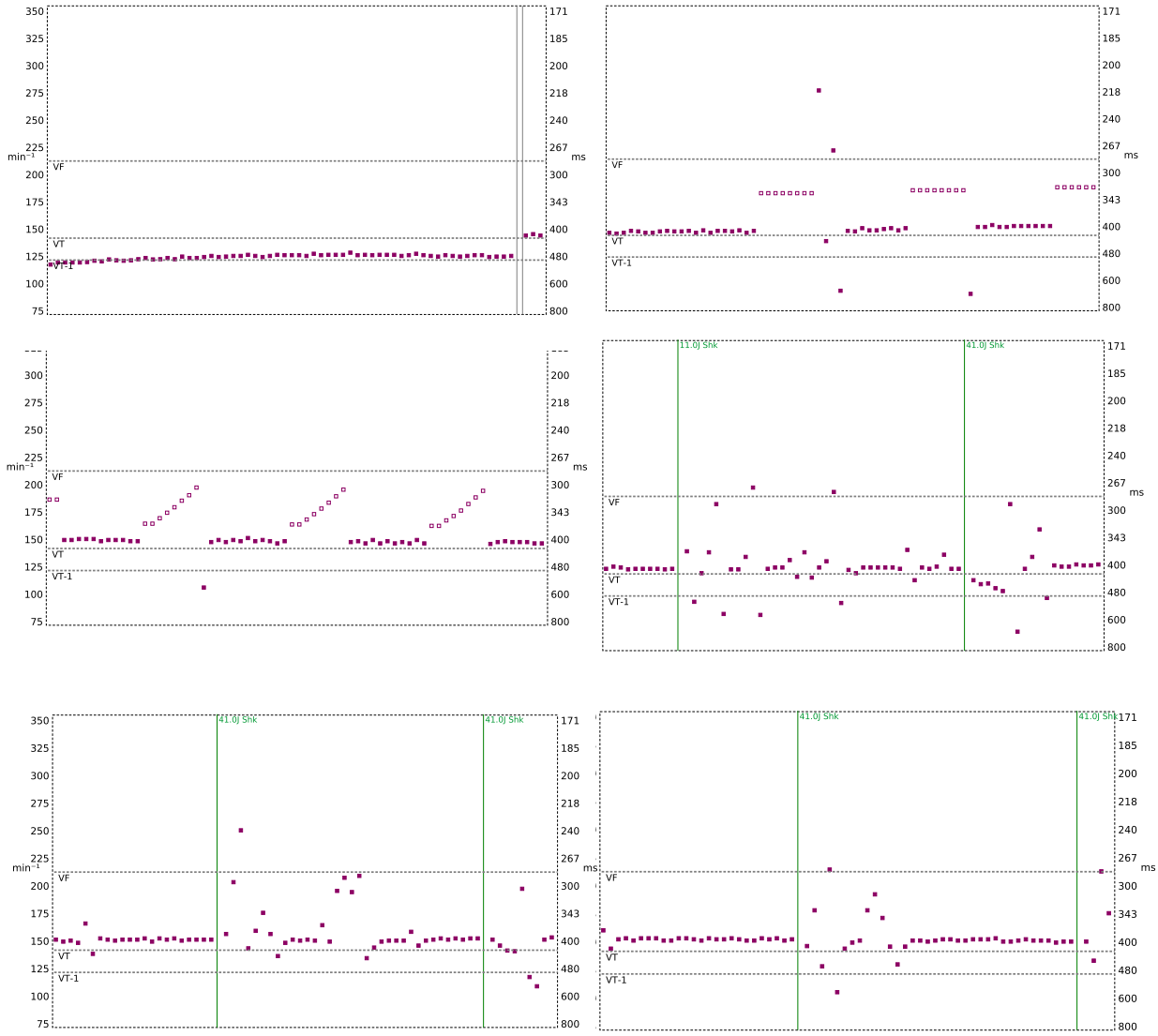

V
6 7
Shock
VT 415
VT 405
VT 410
VT 410
VT 408
VT 405
VT 410
VT 405
VP 328
VP 328
VP 328
VP 328
VP 328
VP 328
VP 328
VP 328
--
VS 690
V-Dur
V-Detect


V
Shock
VT 403
VT 403
VT 398
VT 403
VT 403
VT 400
VT 400
VT 400
VT 400
VT 400
VT 400
VP 323
VP 323
VP 323
VP 323
VP 323
VP 323
VP 323
V-Detect

Pages 7 to 14 are not show, end of the episode:





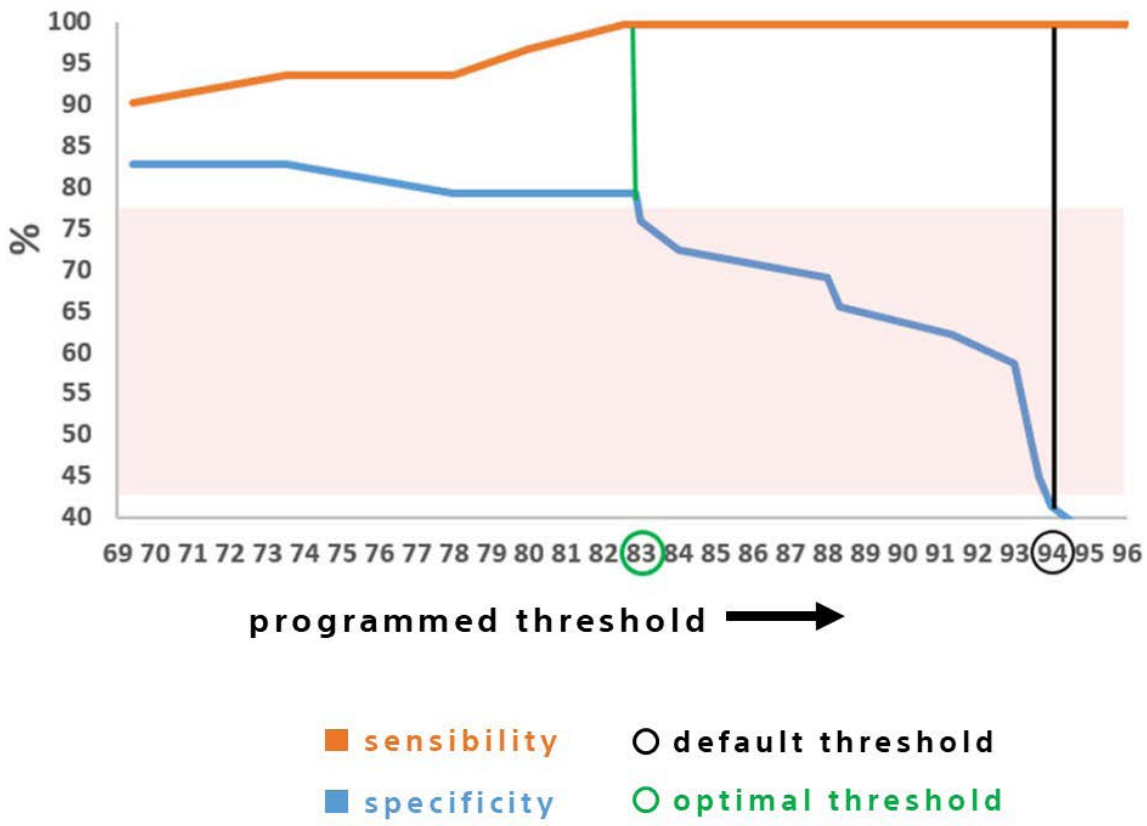


Points to remember

- the percentage of inappropriate therapies has fallen considerably since the very first studies of patients implanted with a defibrillator, and the annual rate is now between 1 and 5%; the reasons for this significant reduction are multifactorial (programming of longer detection times, programming in the first instance of detection zones for tachycardias > 187 beats/minute, programming of discrimination algorithms); it is therefore difficult to precisely isolate the effect of discrimination algorithms
- international guidelines recommend programming discrimination algorithms based

on the manufacturer, up to a rate of 230 beats/minute; for Boston ScientificTM single-chamber devices, discrimination based solely on morphology analysis is suggested, with a 94% correlation coefficient in nominal programming.

- in a multicenter study, this 94% threshold provided perfect sensitivity (100%), but an average specificity of around 41%; this low specificity is all the more problematic since morphology is only applied to initial detection, increasing the risk, as in this patient, that if inappropriate therapy occurs and the rate remains high, all therapies in the VT zone may be delivered
- this low specificity is especially problematic in single-chamber devices since the morphology discriminant is often used in isolation; in a double- or triple-chamber defibrillator, the failure of one discriminant can be corrected by the intervention of another discriminant (e.g. V>A criterion)
- this example of sinus tachycardia is demonstrative: the arrhythmia is initially correctly identified as supraventricular with a sufficient number of correlated cycles; in a second phase, the correlation percentage decreases and the patient receives multiple inappropriate therapies
- in the same multicenter study, lowering the threshold to 83% maintained perfect sensitivity (100%) with a substantial increase in specificity (79%)
- this relatively low specificity at nominal settings compared to other manufacturers, who use relatively similar discrimination, may be explained by the specific manner in which the 8-point ventricular signal is analyzed, favouring sensitivity over specificity (making it easier to detect differences, favouring the occurrence of lower correlation values)
- the nominal value of 94% did not seem appropriate in this patient and was modified which avoided inappropriate therapies during follow-up.
- this clinical case also raises the question of systematically modifying this value in the first instance



This figure shows the differences in specificity as a function of the programmed threshold value; sensitivity remains at 100% up to a value of 83%.

Electrogram morphology discriminators in implantable cardioverter defibrillators: A comparative evaluation. Antonio Frontera, Marc Strik, ... , Pierre Bordachar, Sylvain Ploux. J Cardiovasc Electrophysiol. 2020 Jun;31(6):1493-1506

Scan the QR code to download the study article (PDF)

5 Single-chamber discrimination, Rhythm ID and SRD

Patient

- 71-year-old male with ischemic cardiomyopathy; implanted with an Incepta single-chamber defibrillator

Summary

- discrimination based on Rhythm ID (threshold programmed at 94%)
- tachycardia at 153 beats/minute
- initially untreated episode (Rhythm ID correlated: True)
- episode treated because sustained rate duration (SRD) was satisfied
- 5 shocks delivered

EGM layout

1 irregular tachycardia with ventricular electrograms appearing narrow on the shock channel; alternation between cycles classified as VT-1 and VS; correlation (C = correlated) of all cycles with reference morphology (percentage above the programmed threshold of 94%).

2 end-of-episode marker V-EpsdEnd (corresponding to the previous episode not visualized on this plot), criterion 8/10 not having been satisfied.

3 V-Epsd marker after 8 out of 10 cycles classified as VT-1 or VT

4 end of duration (V-dur marker); discrimination favors SVT; for at least 3 beats/10 (rolling window), the vector is correlated with the reference vector (the last 10 ventricular complexes before the end of duration are correlated).

5 on this cycle, the SRD is satisfied (SRD marker) and, despite a morphology in favor of SVT, therapies for the VT zone begin.

6 Continuation of various VT zone therapies

V-2842: 06 avr. 2021 06:35, TV-1, Fréquence V : 166 min^{-1}

Détail

TV-1 Début événem.

Fréq. V moy.	166 min^{-1}
Détection	ID de Rythme
Référence	05 avr. 2021 06:40
Seuil du RhythmMatch™	94 %

Lors de la Détect-V

Fréq. V moy.	153 min^{-1}
Zone de fréquence	TV-1
RhythmID corrélé	Vrai
RhythmMatch™	99 %
DFS satisfaite	(Faux, arrêt)
Durée limite ATP	Faux

Lors de l'inhibition

RhythmID corrélé	Vrai

Lors de la Détect-V

Fréq. V moy.	160 min^{-1}
Zone de fréquence	TV
DFS satisfaite	Vrai
Durée limite ATP	Faux

Lors de l'inhibition

Stabilité	56 ms

Lors de la Détect-V

Fréq. V moy.	151 min^{-1}
Zone de fréquence	TV
DFS satisfaite	Vrai
Durée limite ATP	Faux

Lors de l'inhibition

Stabilité	63 ms

Lors de la Détect-V

Fréq. V moy.	159 min^{-1}
Zone de fréquence	TV
DFS satisfaite	Vrai
Durée limite ATP	Faux

Lors de l'inhibition

Stabilité	71 ms

Lors de la Détect-V

Fréq. V moy.	169 min^{-1}
Zone de fréquence	TV
DFS satisfaite	Vrai
Durée limite ATP	Faux

Lors de l'inhibition

Stabilité	87 ms

Lors de la Détect-V

Fréq. V moy.	155 min^{-1}
Zone de fréquence	TV
DFS satisfaite	Vrai
Durée limite ATP	Faux

Fin de l'événement 00:28:13

Tentative 1, Pas de traitement V

Temps écoulé	00:00:12

Informations tentative

Traitement tachy désactivé.

Tentative 2, 11 J Choc V

Temps écoulé	00:13:01

Tentative inhibée

Informations sur le choc

Durée de charge	2,2 s
Impédance de la sonde	48 Ω
Polarité de la sonde	Initial

Tentative 3, 41 J Choc V

Temps écoulé	00:14:36

Tentative inhibée

Informations sur le choc

Durée de charge	10,3 s
Impédance de la sonde	50 Ω
Polarité de la sonde	Initial

Tentative 4, 41 J Max Choc V

Temps écoulé	00:15:38

Tentative inhibée

Informations sur le choc

Durée de charge	8,3 s
Impédance de la sonde	50 Ω
Polarité de la sonde	Initial

Tentative 5, 41 J Max Choc V

Temps écoulé	00:17:07

Tentative inhibée

Informations sur le choc

Durée de charge	8,2 s
Impédance de la sonde	51 Ω
Polarité de la sonde	Initial

Tentative 6, 41 J Max Choc V

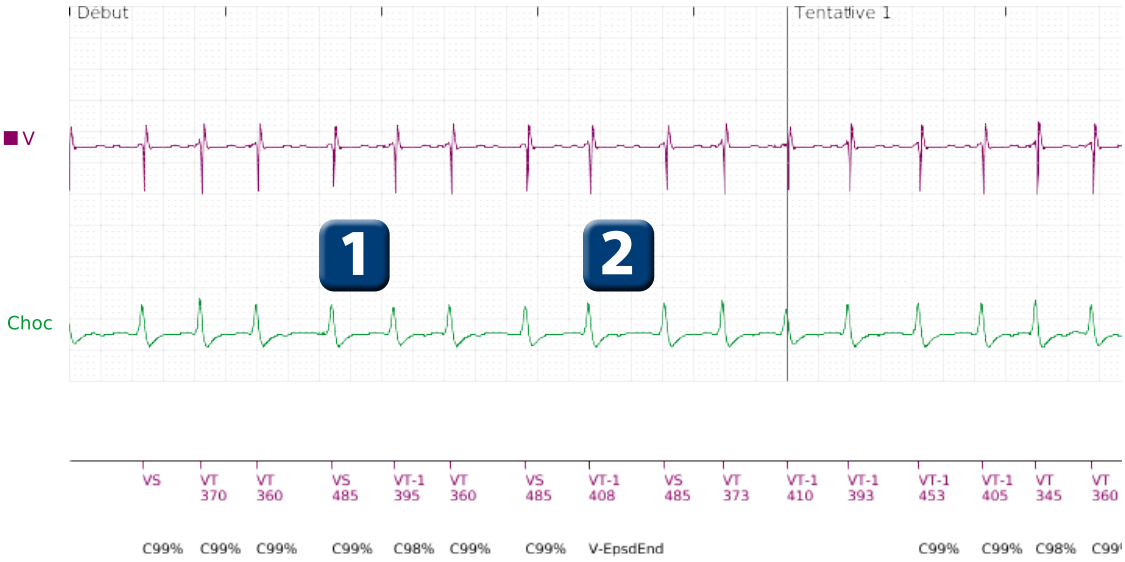
Temps écoulé	00:18:52

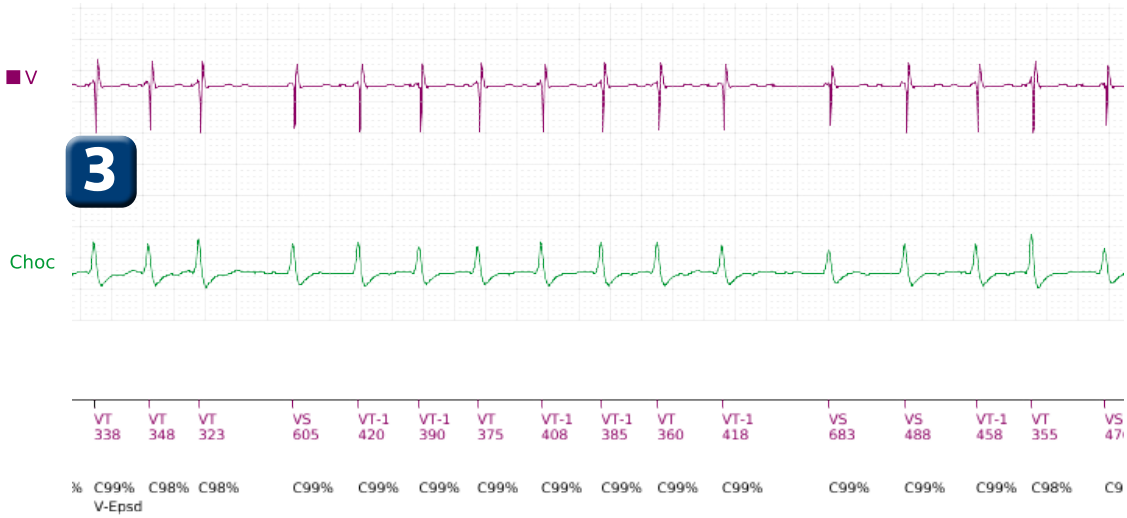
Tentative inhibée

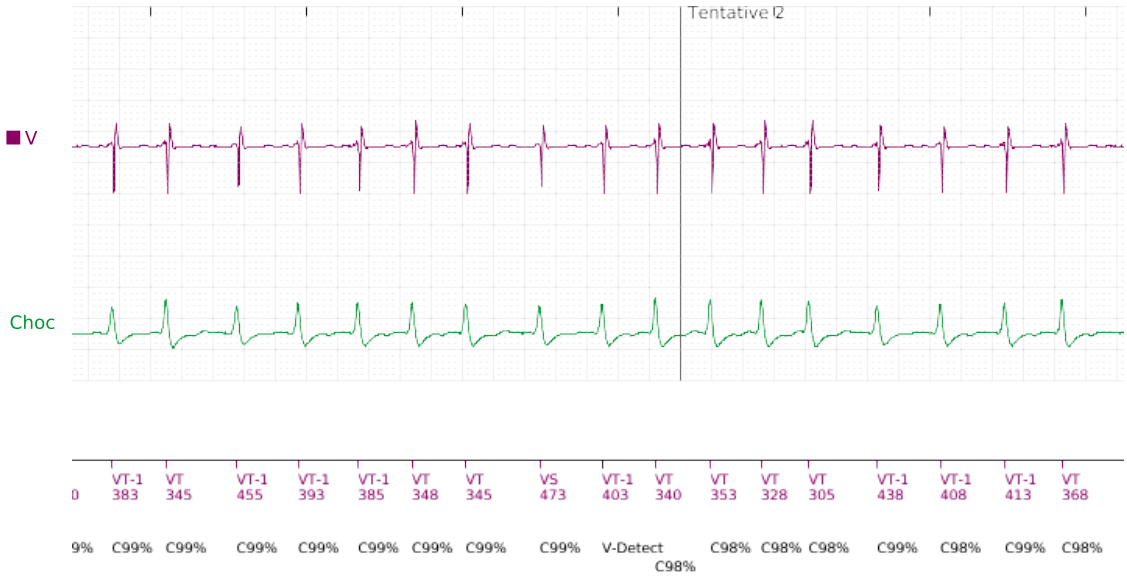
Informations sur le choc

Durée de charge	8,1 s
Impédance de la sonde	50 Ω
Polarité de la sonde	Initial

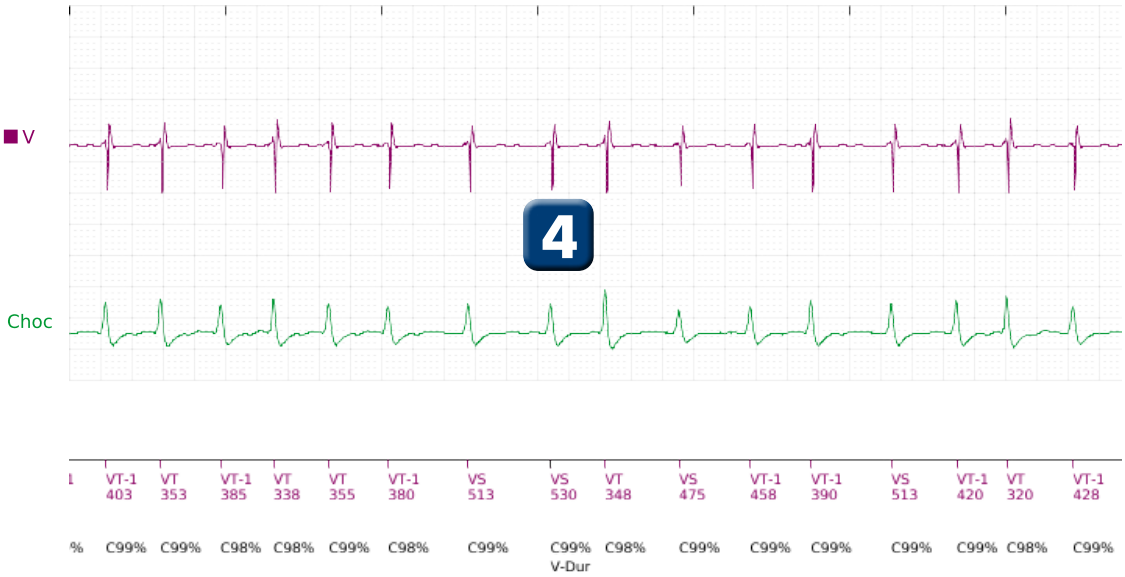
Mode tachy modifié par l'utilisateur


Début
Tentative 1
V
Choc
1
2
VS VT 370 VT 360 VS 485 VT-1 395 VT 360 VS 485 VT-1 408 VS 485 VT 373 VT-1 410 VT-1 393 VT-1 453 VT-1 405 VT 345 VT 360
C99% C99% C99% C99% C98% C99% C99% V-EpsdEnd C99% C99% C98% C99

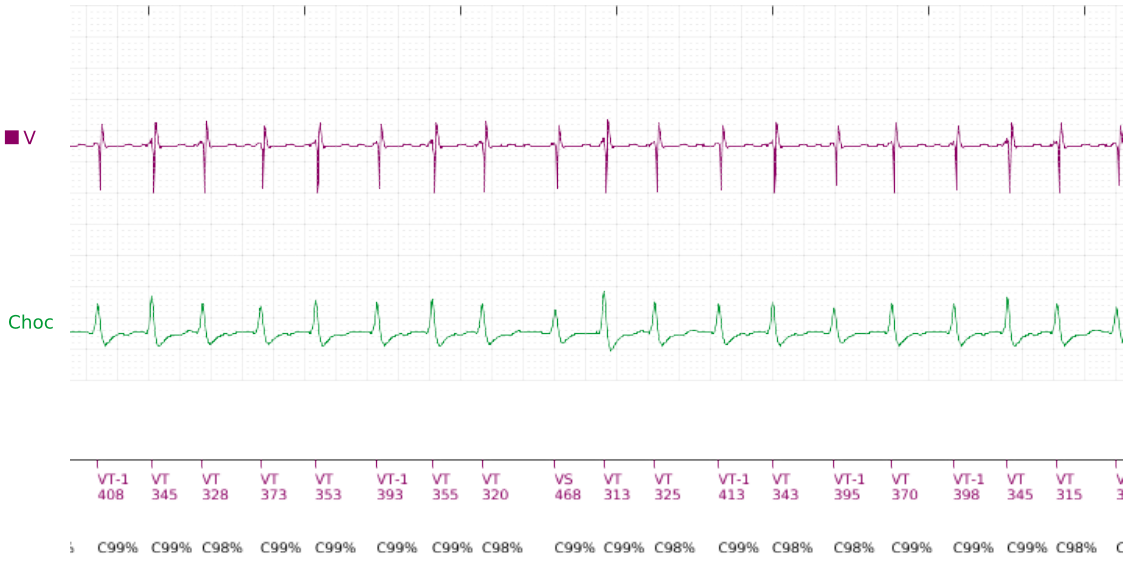

V
3
Choc
VT 338 VT 348 VT 323 VS 605 VT-1 420 VT-1 390 VT 375 VT-1 408 VT-1 385 VT 360 VT-1 418 VS 683 VS 488 VT-1 458 VT 355 VS 47
% C99% C98% C98% V-Epsd C99% C99% C99% C99% C99% C99% C99% C99% C99% C99% C99% C98% C9


Tentative 2
V
Choc
0 VT-1 383 VT 345 VT-1 455 VT-1 393 VT-1 385 VT 348 VT 345 VS 473 VT-1 403 VT 340 VT 353 VT 328 VT 305 VT-1 438 VT-1 408 VT-1 413 VT 368
9% C99% C99% C99% C99% C99% C99% C99% C99% V-Detect C98% C98% C98% C98% C99% C98% C99% C98%

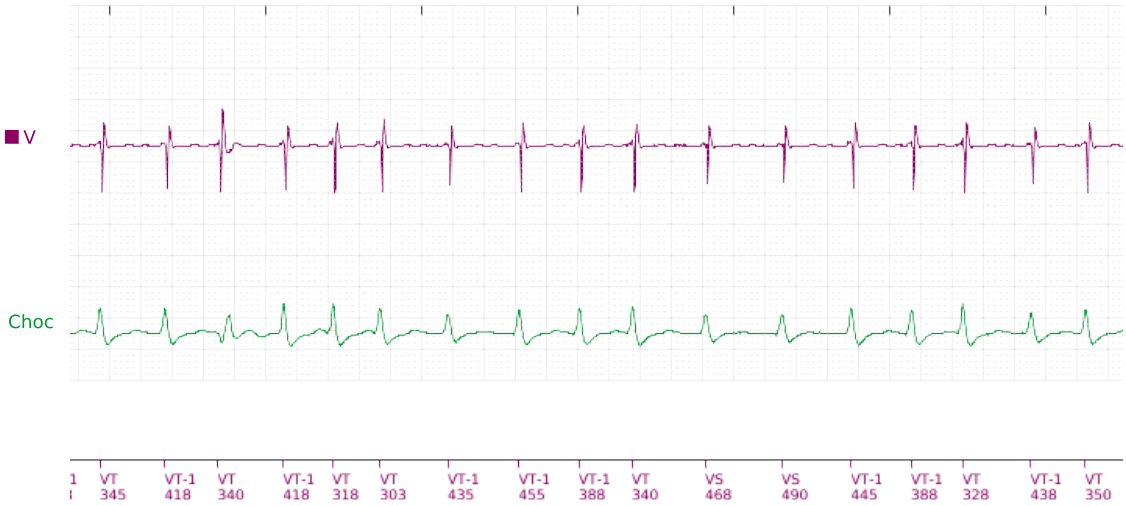

V
Choc
VT-1 460
VT 365
VT 343
VT 343
VT 370
VS 643
VT-1 450
VT 345
VT 325
VT 350
VT-1 458
VS 528
VS 508
VT-1 378
VT-1 398
VT 320
C99% C99% C99% C99% C99% C99% C99% C99% C98% C99% C99% C99% C99% C99% C99% C98%

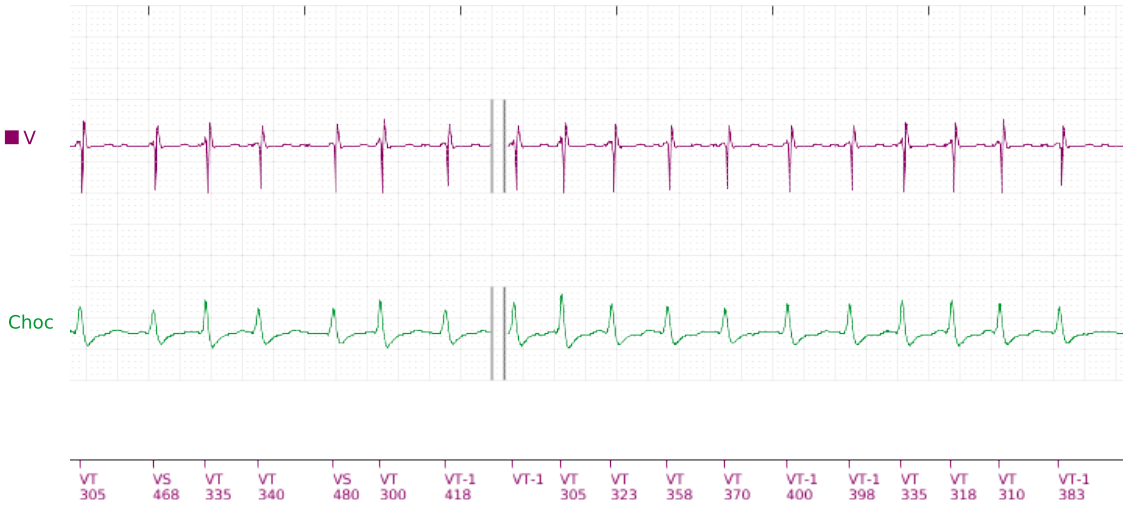

V
4
Choc
VT-1 403
VT 353
VT-1 385
VT 338
VT 355
VT-1 380
VS 513
VS 530
VT 348
VS 475
VT-1 458
VT-1 390
VS 513
VT-1 420
VT 320
VT-1 428
C99% C99% C98% C98% C99% C98% C99% C99% C98% C99% C99% C99% C99% C99% C98% C99%
V-Dur

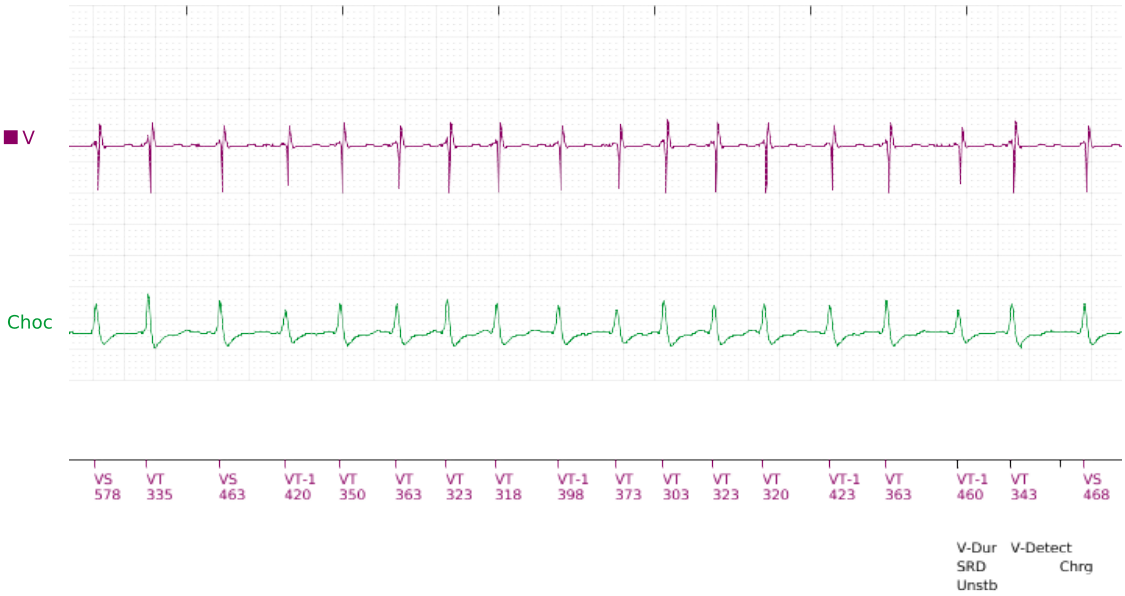

V
Choc
VT-1 448 VT 320 VT-1 433 VT-1 418 VT 355 VT-1 433 VT 363 VT 345 VT 358 VT-1 408 VT-1 380 VT-1 405 VT 343 VT-1 403 VT-1 403 VT-1 400 VT-1
C99% C98% C99% C98% C99% C99% C99% C98% C98% C99% C99% C99% C98% C99% C98% C99% C99%

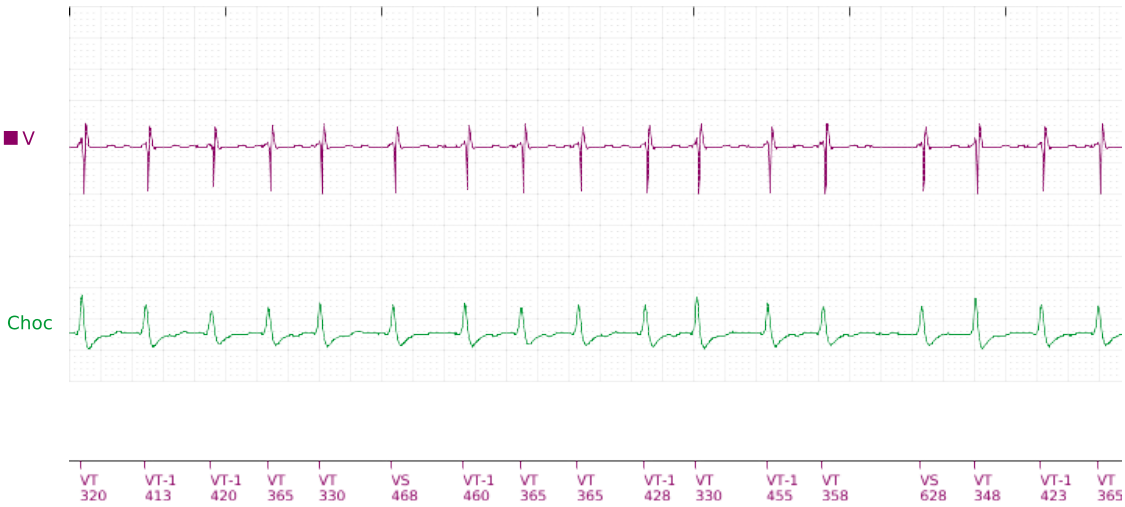

V
Choc
VT-1 408 VT 345 VT 328 VT 373 VT 353 VT-1 393 VT 355 VT 320 VS 468 VT 313 VT 325 VT-1 413 VT 343 VT-1 395 VT 370 VT-1 398 VT 345 VT 315
C99% C99% C98% C99% C99% C99% C99% C98% C99% C99% C98% C99% C98% C98% C99% C99% C99% C98%

Discrimination: 5


V
Choc
1
VT 345
VT-1 418
VT 340
VT-1 418
VT 318
VT 303
VT-1 435
VT-1 455
VT-1 388
VT 340
VS 468
VS 490
VT-1 445
VT-1 388
VT 328
VT-1 438
VT 350


V
Choc
VT 305
VS 468
VT 335
VT 340
VS 480
VT 300
VT-1 418
VT-1
VT 305
VT 323
VT 358
VT 370
VT-1 400
VT-1 398
VT 335
VT 318
VT 310
VT-1 383


V
Choc
VS 578
VT 335
VS 463
VT-1 420
VT 350
VT 363
VT 323
VT 318
VT-1 398
VT 373
VT 303
VT 323
VT 320
VT-1 423
VT 363
VT-1 460
VT 343
VS 468
V-Dur
SRD
Unstb
V-Detect
Chrg


V
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VT 320
VT-1 413
VT-1 420
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VT 330
VS 468
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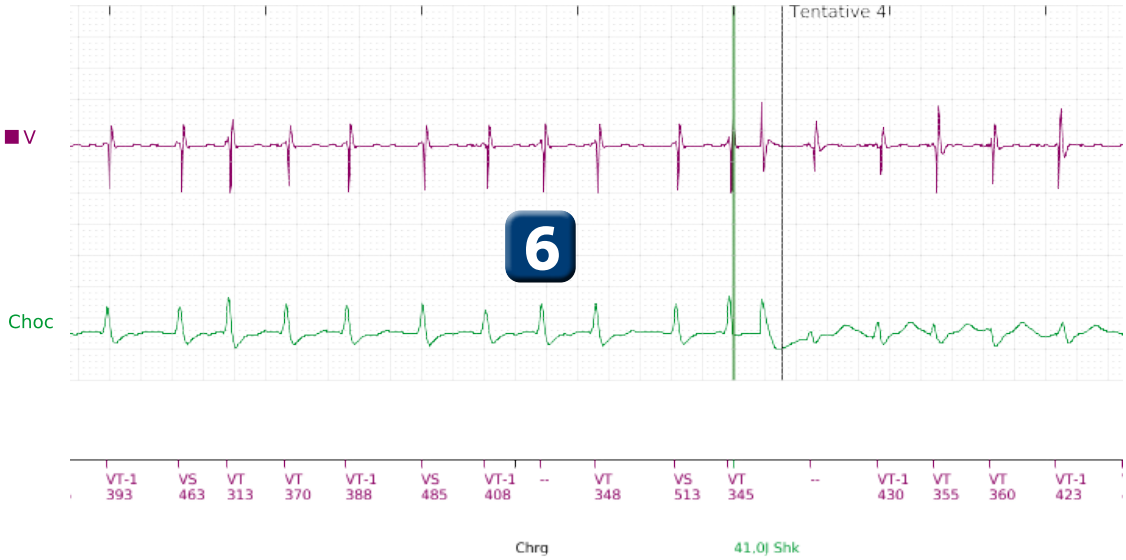
VT 365
VT-1 428
VT 330
VT-1 455
VT 358
VS 628
VT 348
VT-1 423
VT 365


Tentative 4I
V
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Choc
VT-1 393
VS 463
VT 313
VT 370
VT-1 388
VS 485
VT-1 408
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VT 348
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VT-1 430
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VT-1 423
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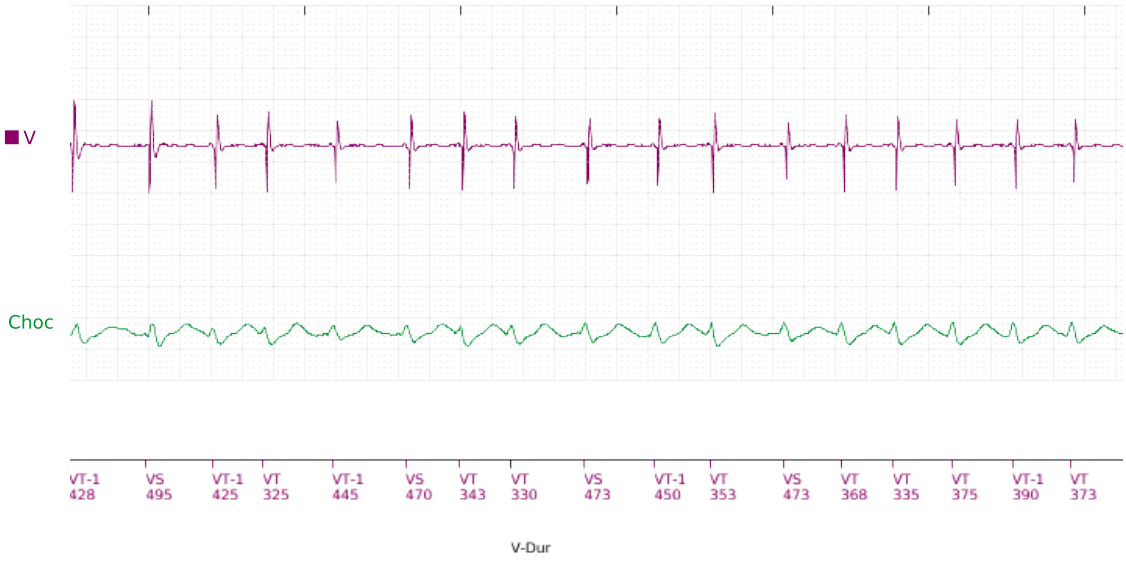
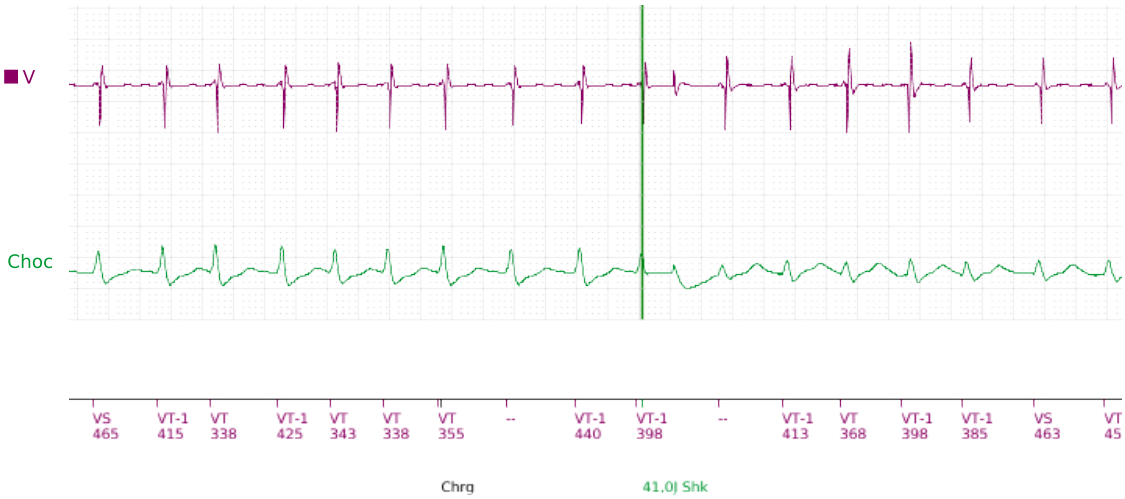
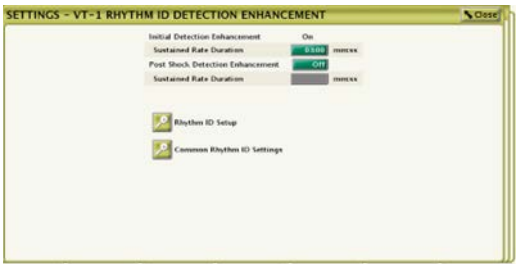

V
Choc
VT-1 428
VS 495
VT-1 425
VT 325
VT-1 445
VS 470
VT 343
VT 330
VS 473
VT-1 450
VT 353
VS 473
VT 368
VT 335
VT 375
VT-1 390
VT 373
V-Dur

Les pages 10 à 18 ne sont pas affichées, fin d'épisode:



Points to remember

- this patient's AF episode is initially well discriminated through morphology analysis and correlation with the reference ventricular electrogram; unfortunately, the defibrillator then inappropriately delivers all the therapies in the VT zone, due to programming of the sustained rate duration (SRD) criterion
- the SRD is a timer which leads to delivery of therapies after a programmable time interval, even if discriminators are in favor of a supra-ventricular origin for the arrhythymia and have initially inhibited the therapies
- SRD is programmable on single, dual and triple chamber defibrillator platforms after selecting the Rhythm ID option or the Onset/Stability option.
- the principle of this timer is based on the fact that the quality of discrimination may be imperfect (diagnosis of SVT for an episode of VT) and that in most sinus tachycardias, the rate remains higher than the arrhythmia detection rate for only a limited time.
- SRD can be programmed separately for VT and VT-1 zones; an independent post-shock SRD value can be programmed
- there is limited data in the literature validating this type of programming; in a study with a timer programmed to 3 minutes, 10% of inappropriate therapies for SVT were observed
- in guidelines recommendations, deprogramming these types timers is advised or programming them over several minutes; in clinical practice, these timers are generally deprogrammed in the first instance and programmed only under certain very specific circumstances (discrimination error, etc.).



A sustained rate duration (SRD) corresponds to a timer that can be programmed for initial detection (3 minutes in this figure) and independently for post-shock detection (deprogrammed in this example).

6 Dual chamber discrimination and V>A

Patient

- 74-year-old male with ischemic cardiomyopathy; implanted with triple-chamber defibrillator

Summary

- episode of VT at 156 beats/min requiring a burst of ATP
- at initial detection, discrimination is based on the Rythm ID algorithm
- Rate V > A: true

EGM layout

1. spontaneous rhythm in the atrium and biventricular pacing
2. abrupt onset of regular tachycardia, with atrioventricular dissociation (more ventricles complexes than atrial complexes, indicating a ventricular origin for the arrhythmia)
3. criterion 8/10 fulfilled (V-Epsd); QRS complexes judged to be uncorrelated (U, correlation percentage below the programmed threshold percentage of 94%)
4. V>A criterion verified: diagnosis of VT (V-Detect)
5. ATP burst
6. efficient burst and arrhythmia termination

V-17: 20 sept. 2022 10:20, TV, Fréquence A : 55 min^{-1}, Fréquence V : 162 min^{-1}

Détail

TV Début événem.

Fréq. A moy.	55 min^{-1}
Fréq. V moy.	162 min^{-1}
Détection	ID de Rythme
Référence	18 sept. 2022 03:01
Seuil du RhythmMatch™	94 %

Lors de la Détect-V

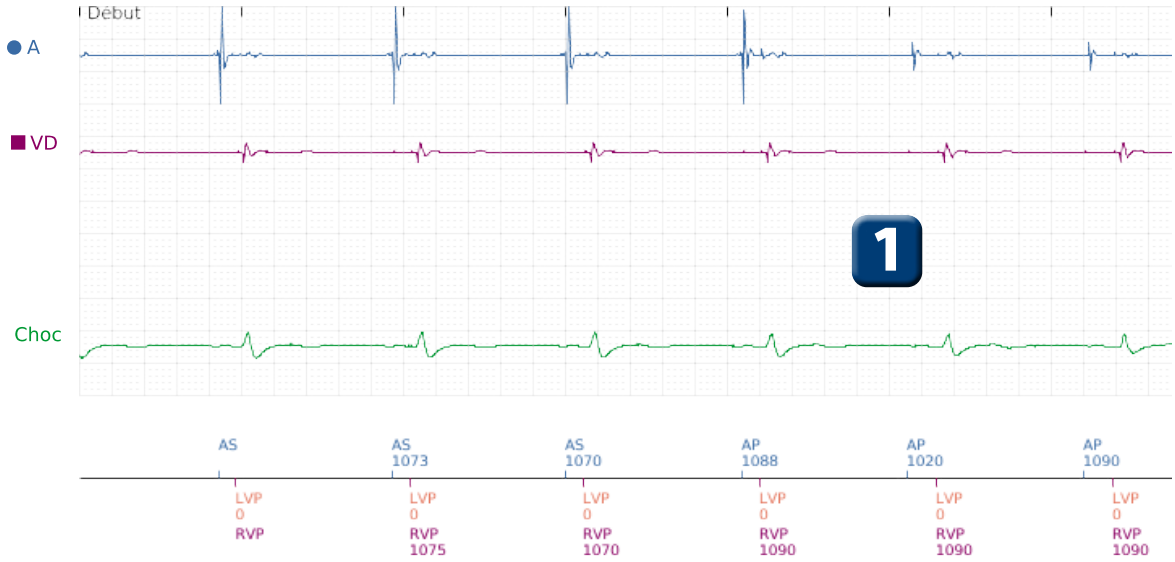
Fréq. A moy.	62 min^{-1}
Fréq. V moy.	156 min^{-1}
Zone de fréquence	TV
Stabilité	4 ms
Fréquence V>A	Vrai
Fib A	Faux
RhythmID corrélé	Faux
RhythmMatch™	77 %
DFS satisfaite	(Faux, arrêt)
Durée limite ATP	Faux

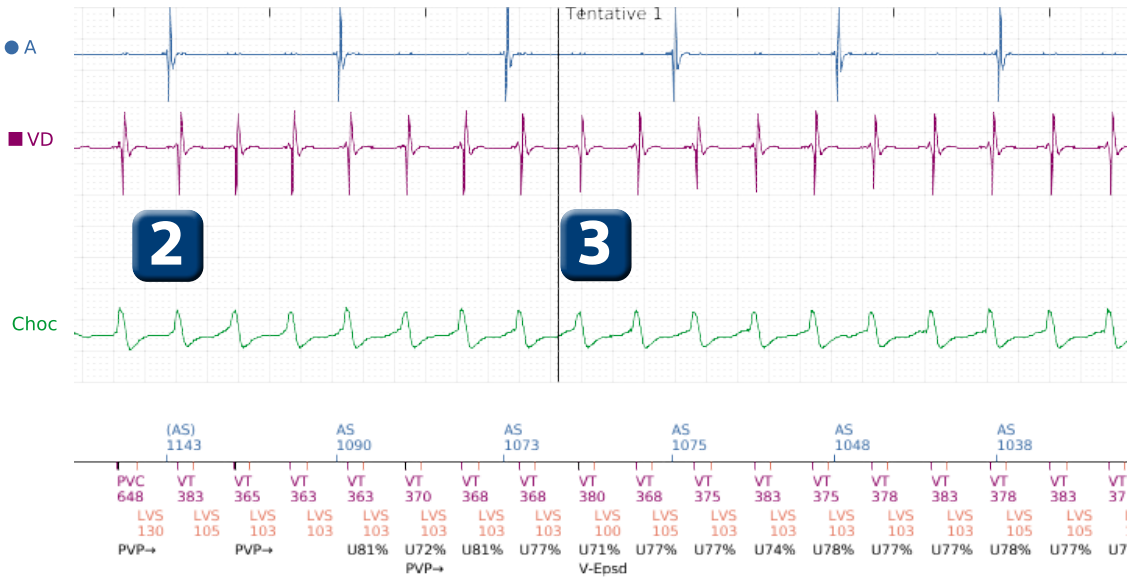
Tentative 1, Salve ATP V

Temps écoulé	00:00:15
Informations ATP	
Nombre de salves	1

Fin de l'événement 00:00:30

EGM affiché à 25 mm par seconde




A
VD
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Tentative 1
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AS 1090
AS 1073
AS 1075
AS 1048
AS 1038
PVC 648
VT 383
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VT 380
VT 368
VT 375
VT 383
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LVS 130
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A
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Choc
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AS 1023
AS
AS 1025
AS 1010
AS 1005
AS 988
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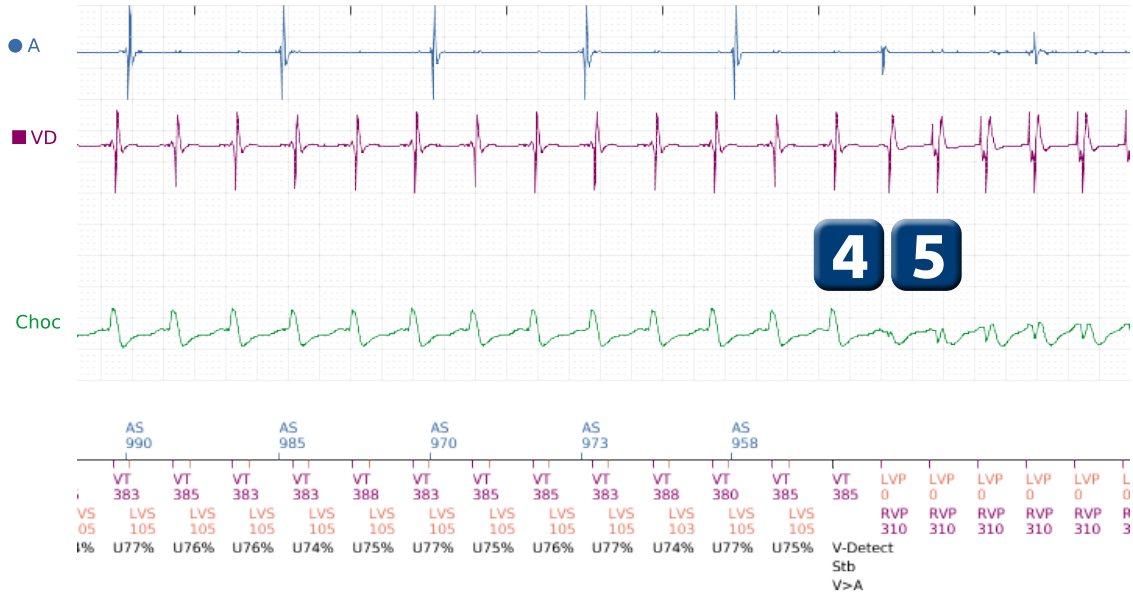
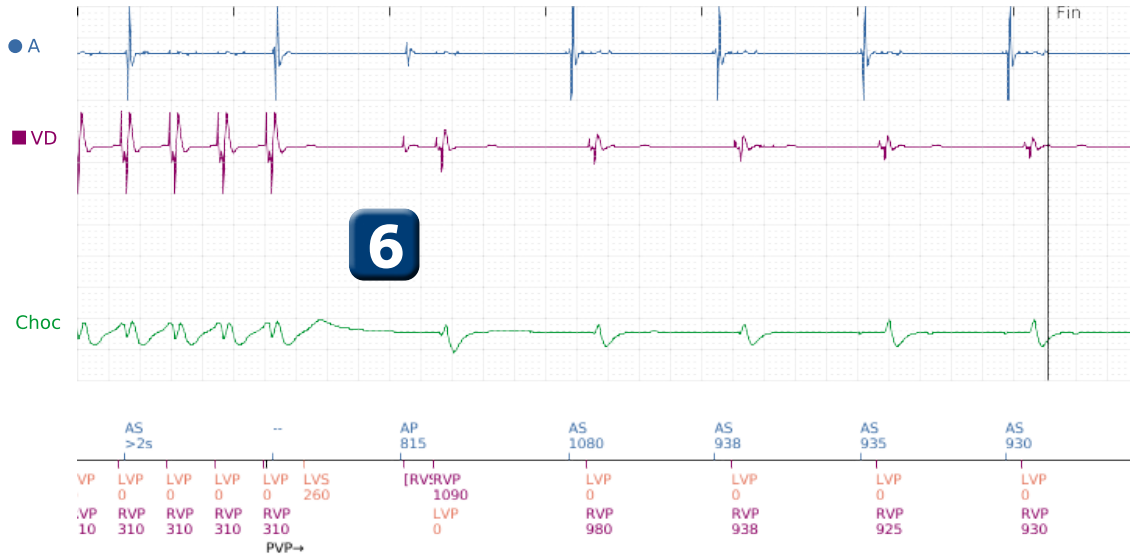
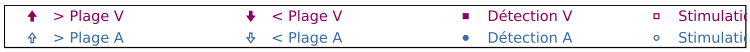

A
VD
Choc
4
5
AS 990
AS 985
AS 970
AS 973
AS 958
VT 383
VT 385
VT 388
VT 380
LVS 105
LVS 103
U77%
U76%
U74%
U75%
LVP 0
RVP 310
V-Detect
Stb
V>A


A
VD
Choc
Fin
6
AS >2s
AP 815
AS 1080
AS 938
AS 935
AS 930
LVP 0
RVP 310
RVP 1090
RVP 980
RVP 925
RVP 930
PVP→


> Plage V
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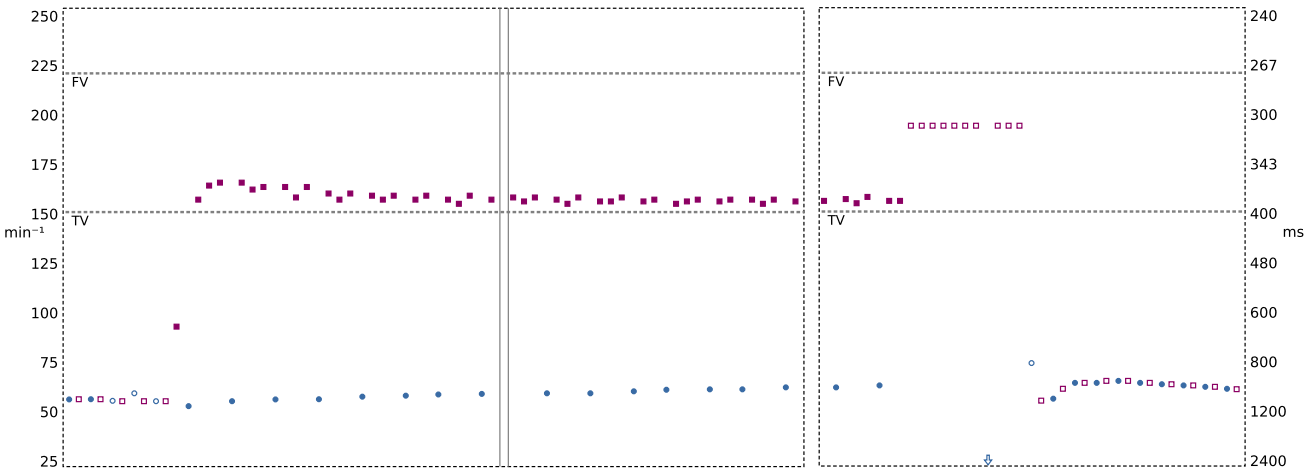
Détection V
> Plage A
< Plage A
Détection A


FV
TV
min⁻¹
ms
250
225
200
175
150
125
100
75
50
25
240
267
300
343
400
480
600
800
1200
2400

Points to remember

- a dual-chamber defibrillator allows comparison of atrial and ventricular rates; for both the clinician and the defibrillator, the presence of a ventricular rate faster than the atrial rate confirms the ventricular origin of the tachycardia
- the V rate > A rate criterion can be programmed on a dual- or triple-chamber defibrillator by selecting the Rhythm ID or Onset/Stability option; this criterion takes precedence over the other associated discrimination criteria, which means that if this condition is true (V>A), it supersedes all the other programmed discriminators and the diagnosis of VT is made.
- the analysis is performed by comparing the mean rate of the last 10 ventricular intervals preceding the end of the duration with the mean rate of the last 10 atrial intervals preceding the end of the duration
- if the mean ventricular rate exceeds the mean atrial rate by at least 10 beats/minute, it is considered to be faster than the atrial rate (indicated as True in the Episode Details report), and treatment may be initiated.
- if the mean ventricular rate is not higher than the mean atrial rate by at least 10 beats/minute (indicated as False in the Episode Detail report), treatment may be inhibited if the other discriminants favor of SVT
- in this patient, the difference in rate between the atria (62 beats/minute) and the ventricles (156 beats/minute) is obvious, justifying the diagnosis of VT

7 Dual-chamber discrimination, atrial refractory periods and V>A criterion

Patient

- 66-year-old male with severe ischemic cardiomyopathy; implanted with a dual-chamber defibrillator

Summary

- initial diagnosis of supraventricular tachycardia based on Rhythm ID with no treatment
- subsequent diagnosis of a VT with a series of 5 ATP bursts

EGM layout

1. probable sinus tachycardia with 1/1 AV relationship; alternating cycles classified as VS and VT-1
2. criterion 8/10 met
3. at the end of the duration, no therapy is delivered; the rhythm is stable and the tachycardia vectors are correlated with the reference vector.
4. ongoing cycle-by-cycle analysis
5. probable variation in the time at which the R wave is detected by the ventricular lead, explaining the variability of ventricular intervals; rhythm considered unstable; vectors remain correlated, no therapy delivered
6. Stability criterion met again
7. probable atrial extrasystole with some irregularity to the rhythm
8. new atrial extrasystole; as the PR is relatively long, the atrial extrasystole occurs at the same time as ventricular sensing of the R wave; it falls within the atrial refractory period after ventricular sensing and is not sensed.

9 since the atrial extrasystole is not counted, the subsequent compensatory rest is responsible for a false slowing of the atrial rhythm compared to the ventricular rhythm; V>A criterion is satisfied (comparison of atrial and ventricular rate over the previous 10 cycles); this criterion takes precedence over all others; decision to treat

10 first ATP burst

11 continuation of sinus tachycardia

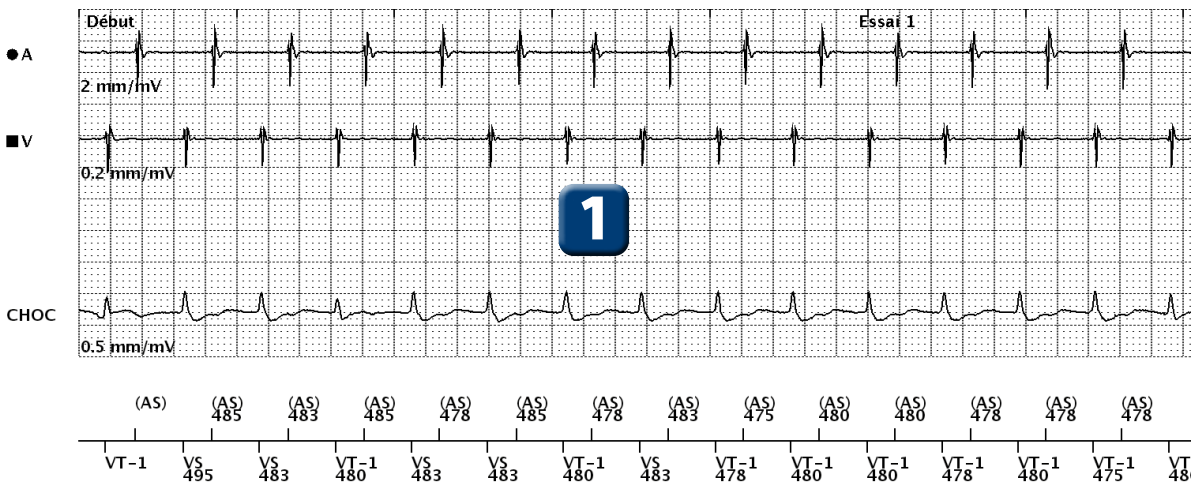
12 second ATP burst

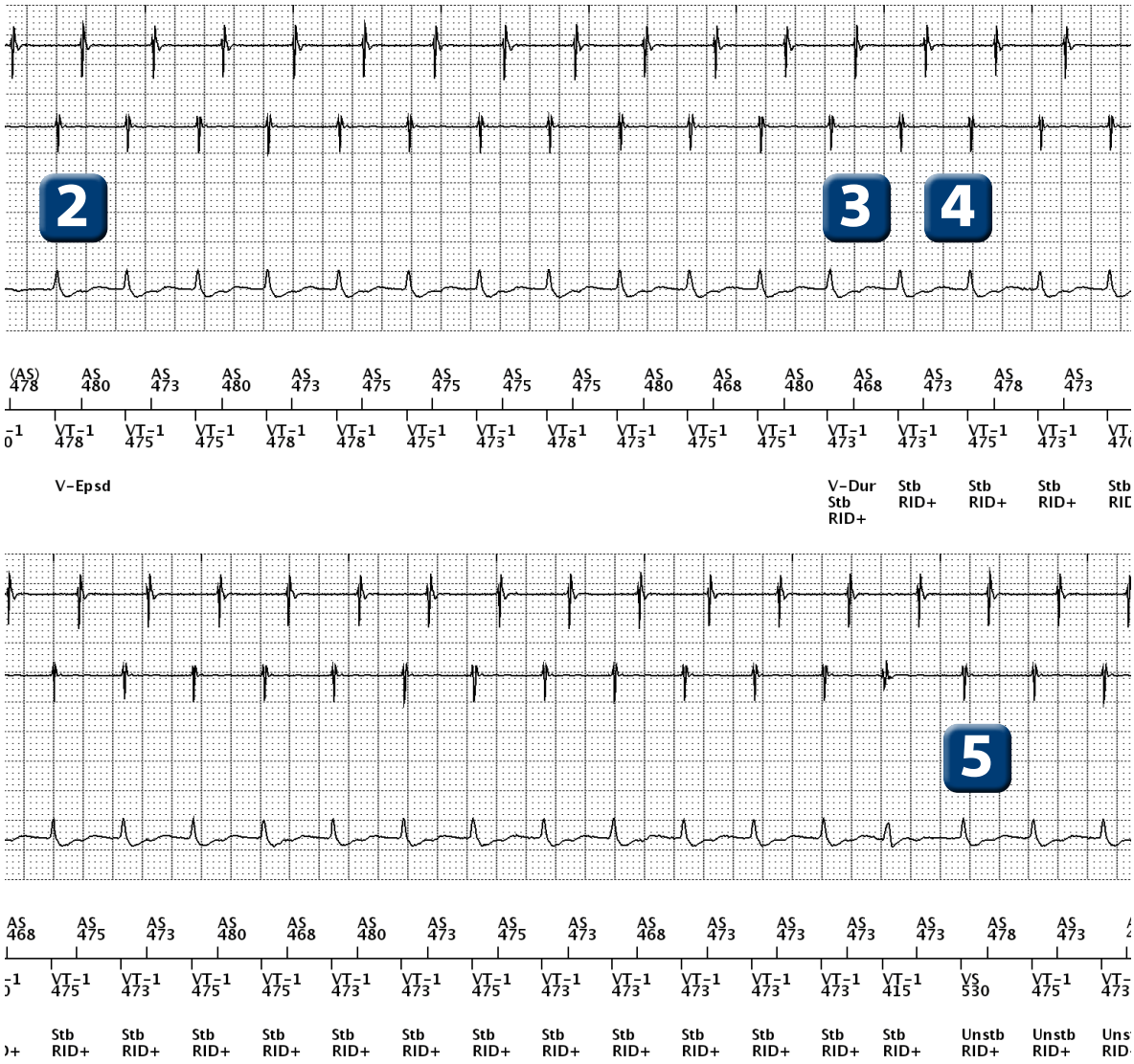
13 third ATP burst

14 fourth ATP burst

15 fifth ATP burst

16 slowing of sinus rate below VT-1 zone and end of episode

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V-Epsd
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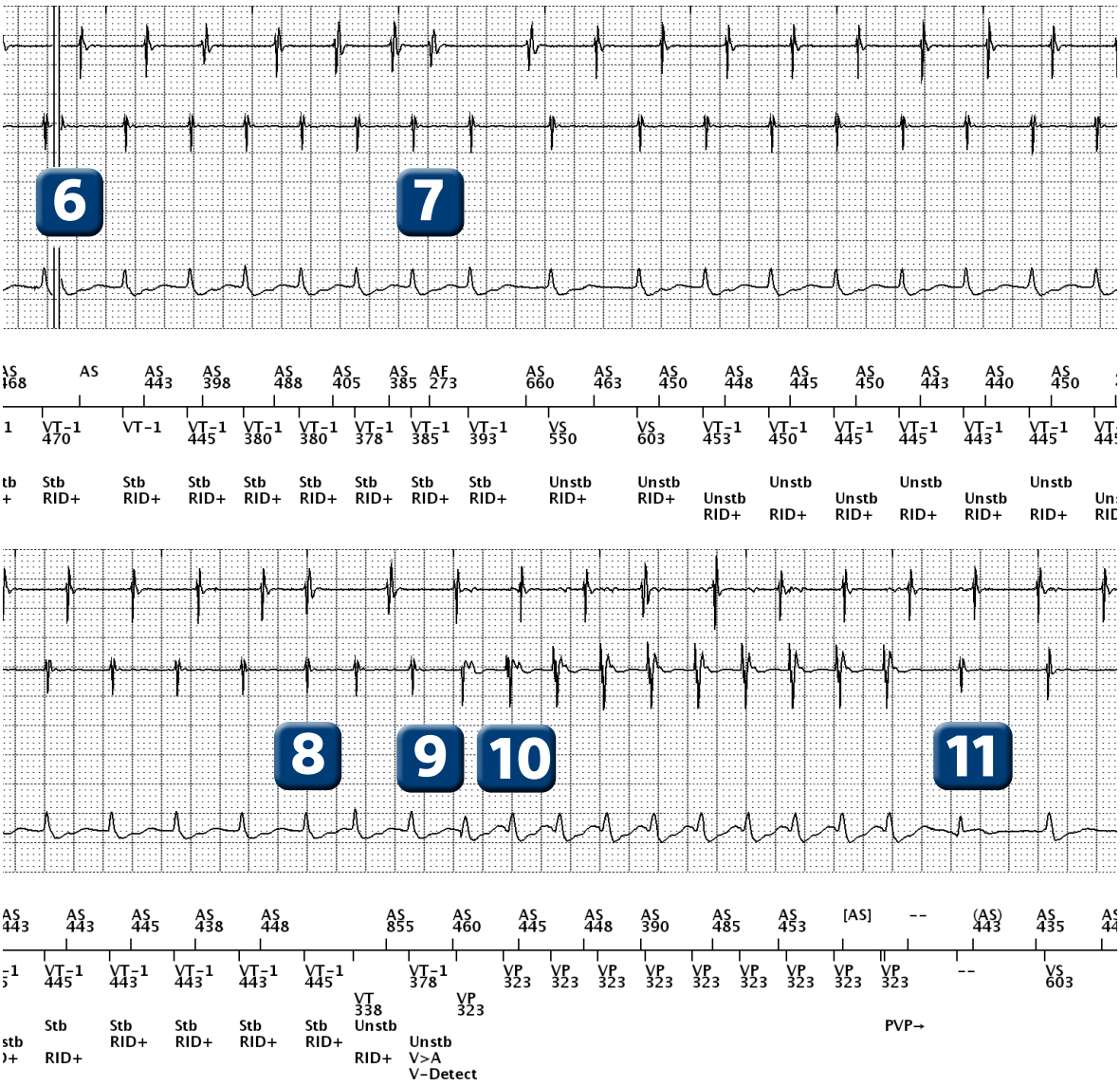
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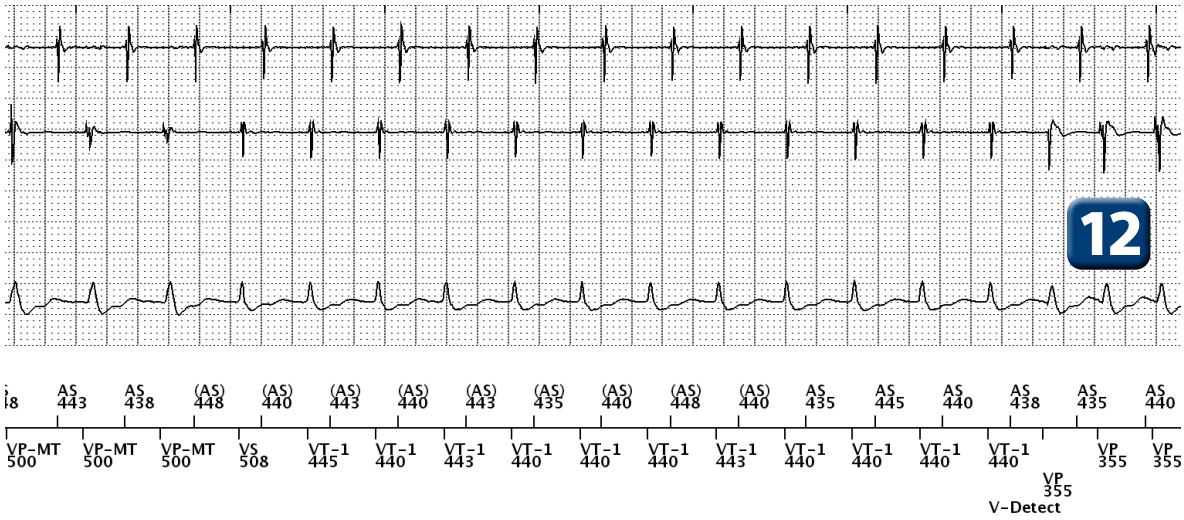
12
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VP-MT 500
VP-MT 500
VP-MT 500
VS 508
VT-1 445
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VT-1 443
VT-1 440
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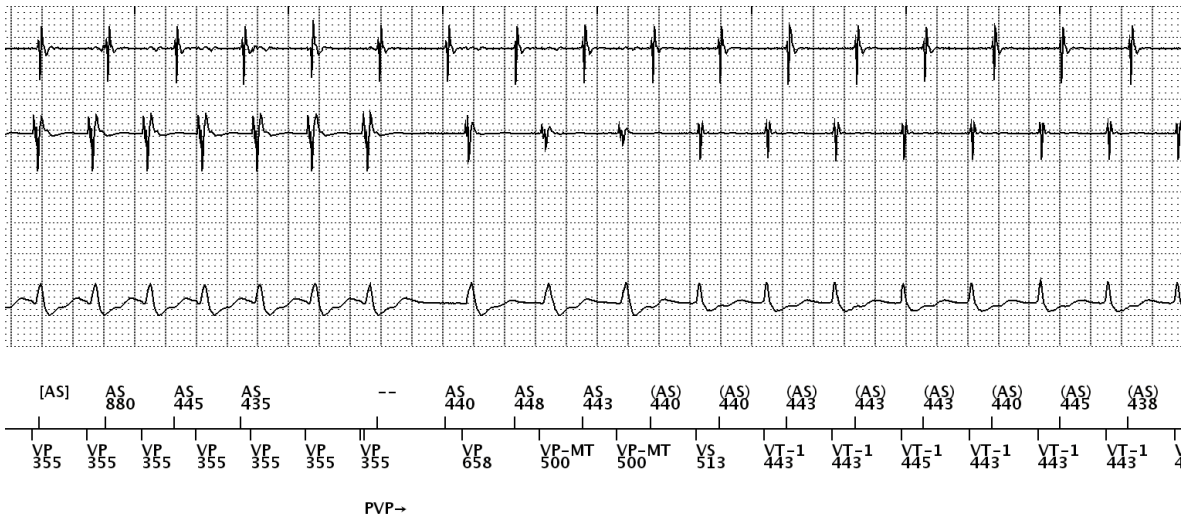
VP 355
VP 355
V-Detect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AS 435
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AS 443
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(AS) 438
VP 355
VP 355
VP 355
VP 355
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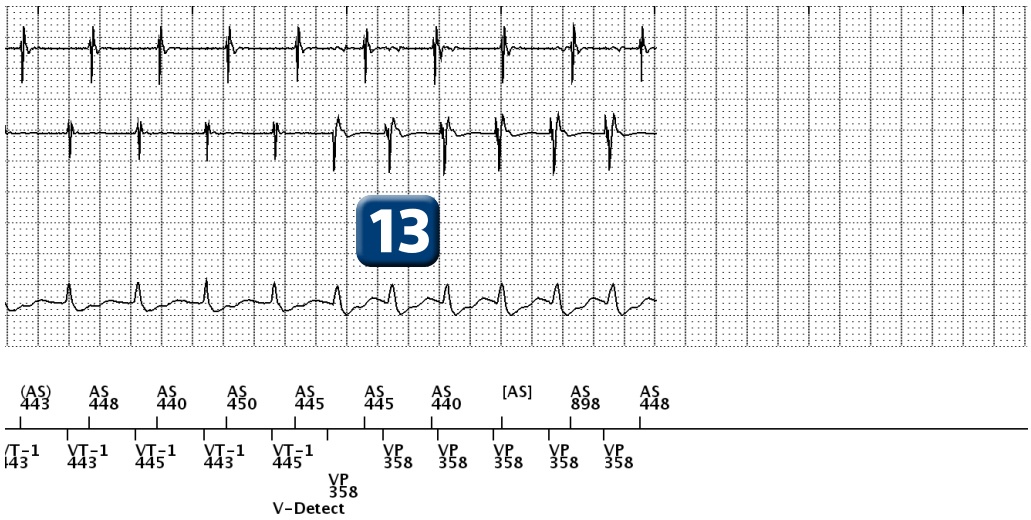
VP 355
VP 355
VP 658
VP-MT 500
VP-MT 500
VS 513
VT-1 443
VT-1 443
VT-1 445
VT-1 443
VT-1 443
VT-1 443
PVP→


13
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AS 448
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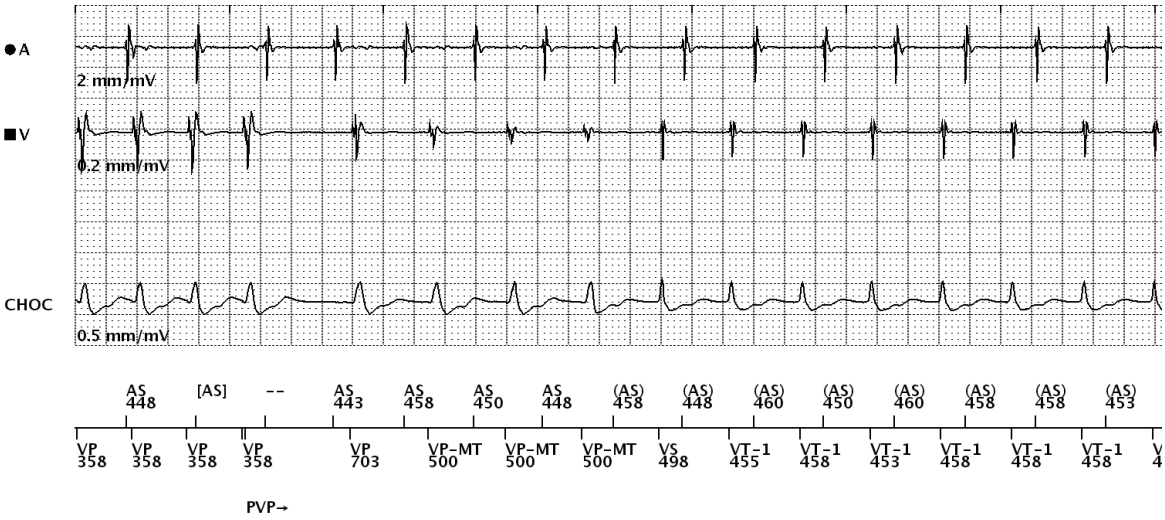
VP 358
V-Detect


●A
2 mm/mV
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0.2 mm/mV
CHOC
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[AS]
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AS 443
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AS 450
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VP 358
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VP 358
VP 703
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VT-1 453
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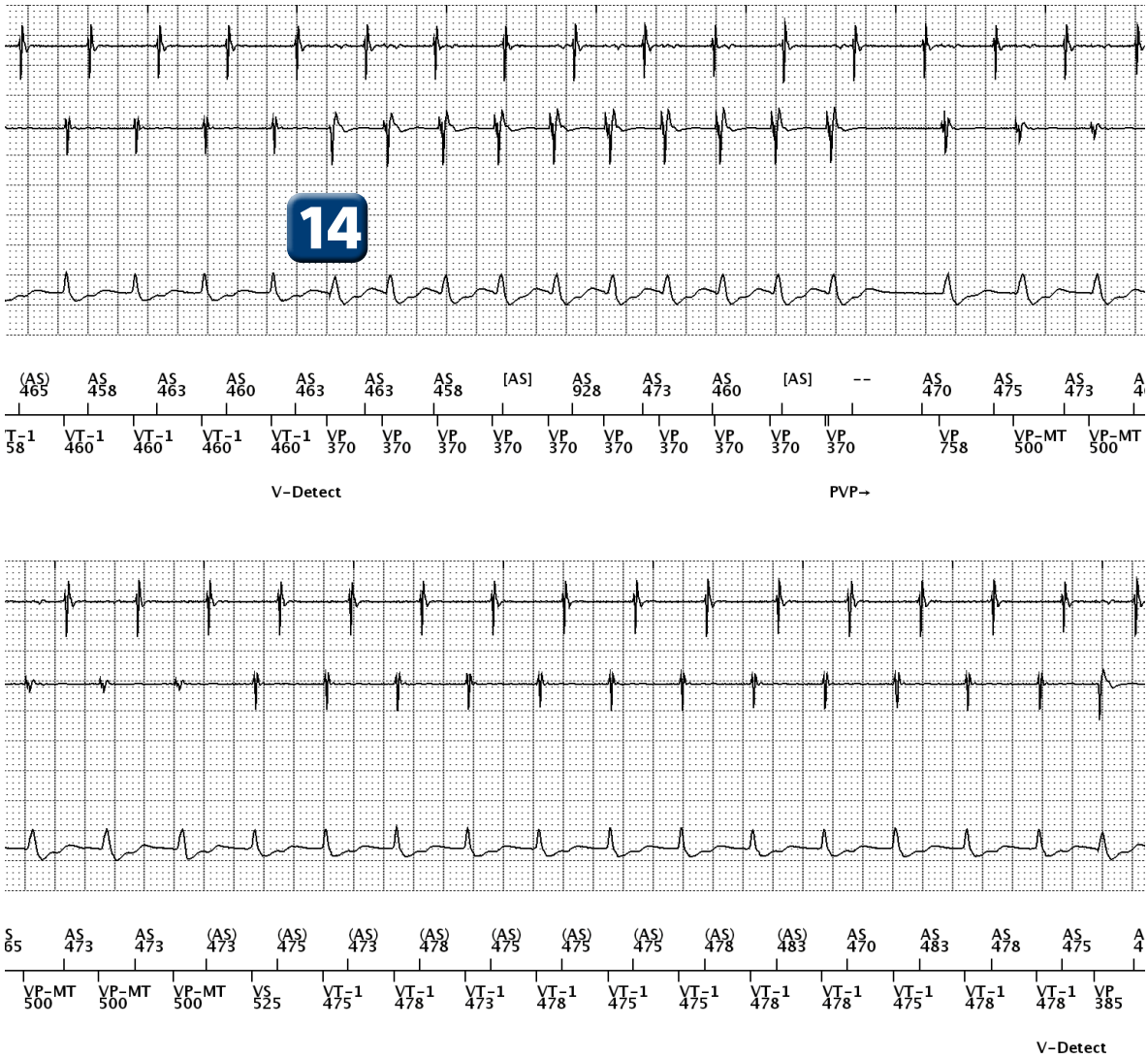
VT-1 458
VT-1 458
PVP→


14
(AS) AS AS AS AS AS AS [AS] AS AS AS [AS] -- AS AS AS A
465 458 463 460 463 463 458 928 473 460 470 475 473
T-1 VT-1 VT-1 VT-1 VT-1 VP VP VP VP VP VP VP VP VP VP VP VP VP-MT VP-MT
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V-Detect
PVP→
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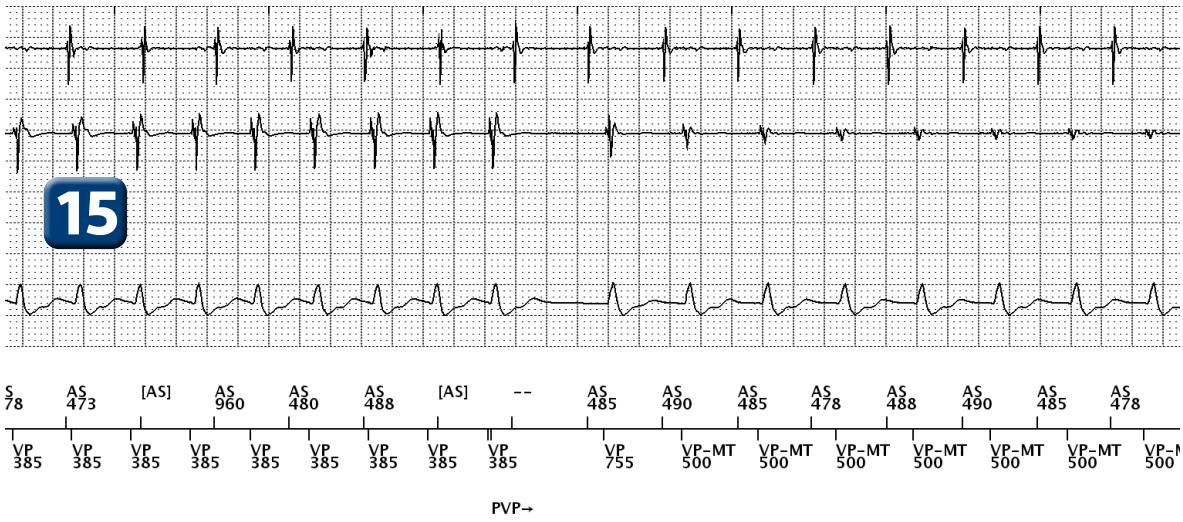
V-Detect


15
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AS 960
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AS 488
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VP 385
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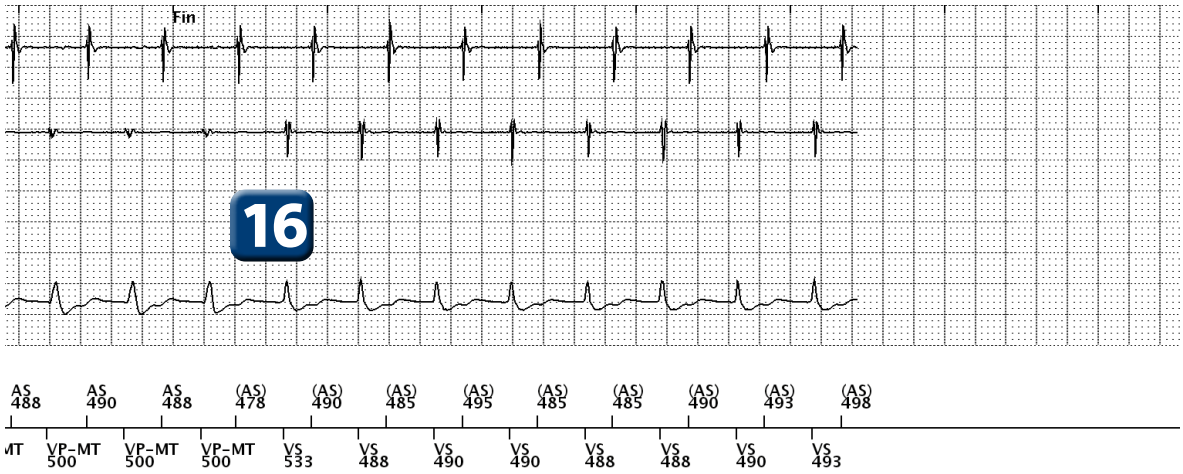
PVP→


Fin
16
AS 488
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AS 488
(AS) 478
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VP-MT 500
VS 533
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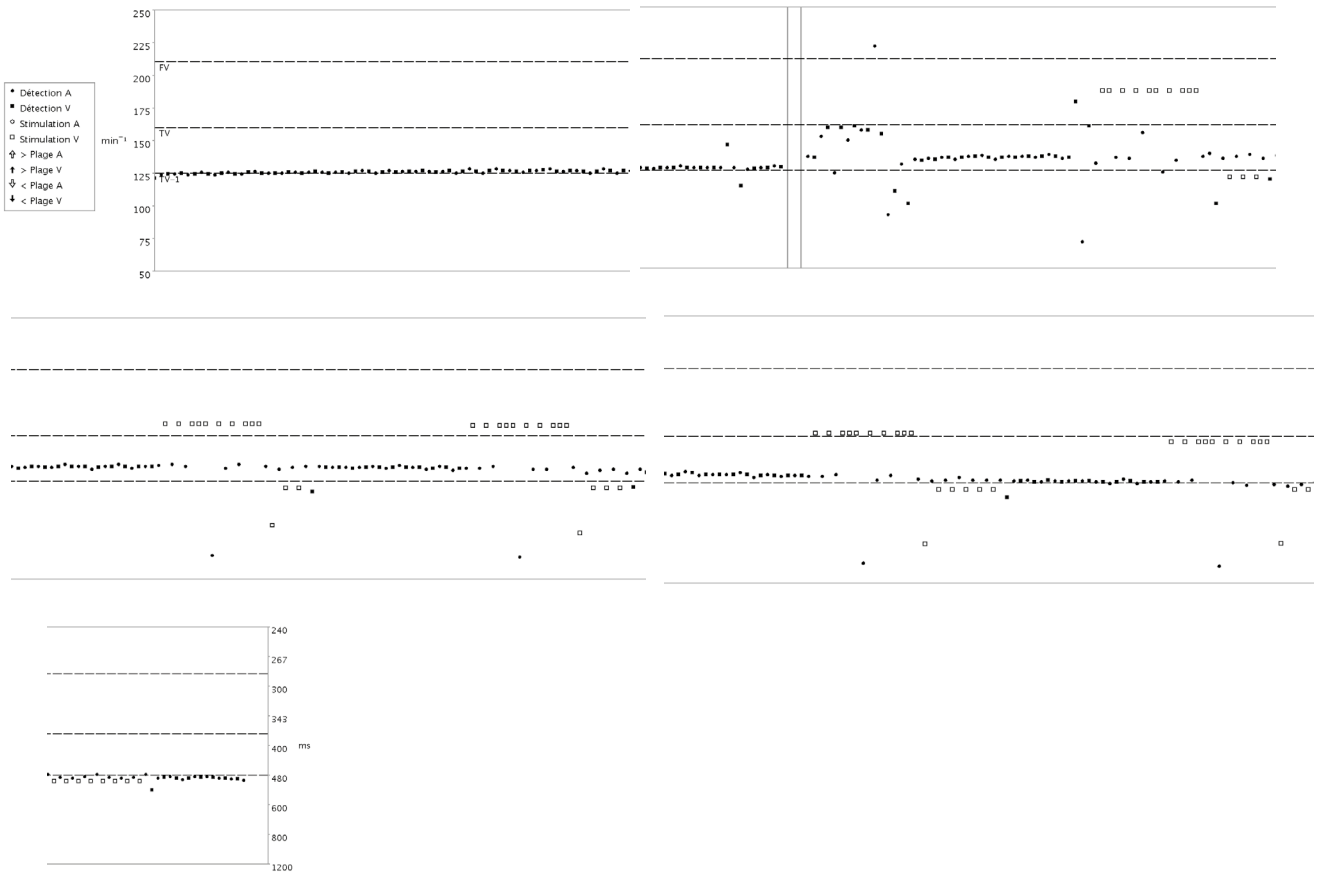
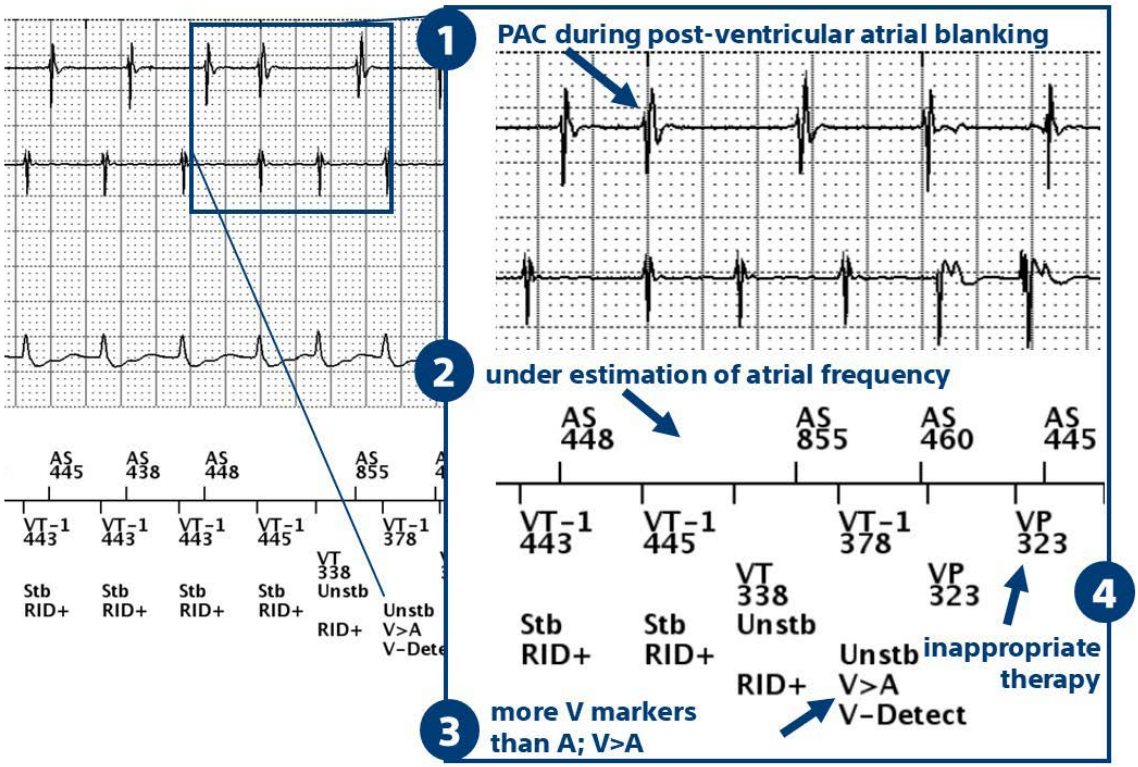


Points to remember

- this episode corresponds to a sinus tachycardia that was initially discriminated correctly; when the vectors are correlated, the device inhibits therapies
- the device is deceived during a second phase by the non-sensed atrial extrasystole that falls in the refractory period; in fact, the V>A criterion takes precedence over all other criteria, including morphology analysis
- as a general rule, the V>A criterion enables correct classification of the majority of ventricular tachycardias (atrioventricular dissociation is found in at least 80% of VTs); implementation of this criterion implies good atrial sensing; when the patient has imperfect atrial sensing (small amplitude signals or functional under- sensing, with atrial

signals falling in the refractory period), this criterion, which takes precedence over other discriminants (morphology, stability, etc), systematically leads to a diagnosis of VT and must therefore be deprogrammed.

- for this patient, a first solution could be to avoid overlap between the detection/ treatment zones and faster physiological rates
- another option is to preferentially use discrimination based on vector analysis, which seems perfectly suited to this patient; this involves deprogramming the V>A criterion responsible for the inappropriate therapies.



On this tracing, we can see that the morphology analysis is in favor of SVT (RID+); an atrial extrasystole falls into the post-ventricular atrial blanking, is not sensed and distorts the atrial rate calculation; the V>A criterion is satisfied and inappropriate therapy is delivered (burst).

8 Dual-chamber discrimination and tachycardia

Patient

- 54-year-old female with implanted with dual-chamber defibrillator for dilated cardiomyopathy

Summary

- episode detected in VT-1 zone at 159 beats/minute
- Rhythm ID discrimination
- criterion V>A : False
- Rhythm ID correlated: True

EGM layout

1. probable sinus tachycardia with spontaneous conduction; cycles classified as VS
2. acceleration of heart rate with cycles classified as VT-1
3. correlated ventricular complexes (percentage exceeding the programmed threshold value of 94%)
4. V-Epsd marker after 8 cycles in VT-1 zone
5. end of duration, all previous complexes correlated
6. cycle-by-cycle analysis of morphology continues; heart rate slows down and cycles are classified as VS

V-415: 05 Mar 2022 12:29, VT-1, A Rate: 161 min^{-1}, V Rate: 161 min^{-1}

Detail

VT-1 Event Onset

Avg A Rate	161 min^{-1}
Avg V Rate	161 min^{-1}
Detection	Rhythm ID
Template	02 Mar 2022 03:23
RhythmMatch™ Threshold	94 %

At V-Detect

Avg A Rate	159 min^{-1}
Avg V Rate	159 min^{-1}
Rate Zone	VT-1
Stability	(4 ms, Off)
V>A Rate	(False, Off)
AFib	(False, Off)
RhythmID Correlated	True
RhythmMatch™	98 %
SRD Met	(False, Off)
ATP Timeout	False

Attempt 1, Non Therapy V

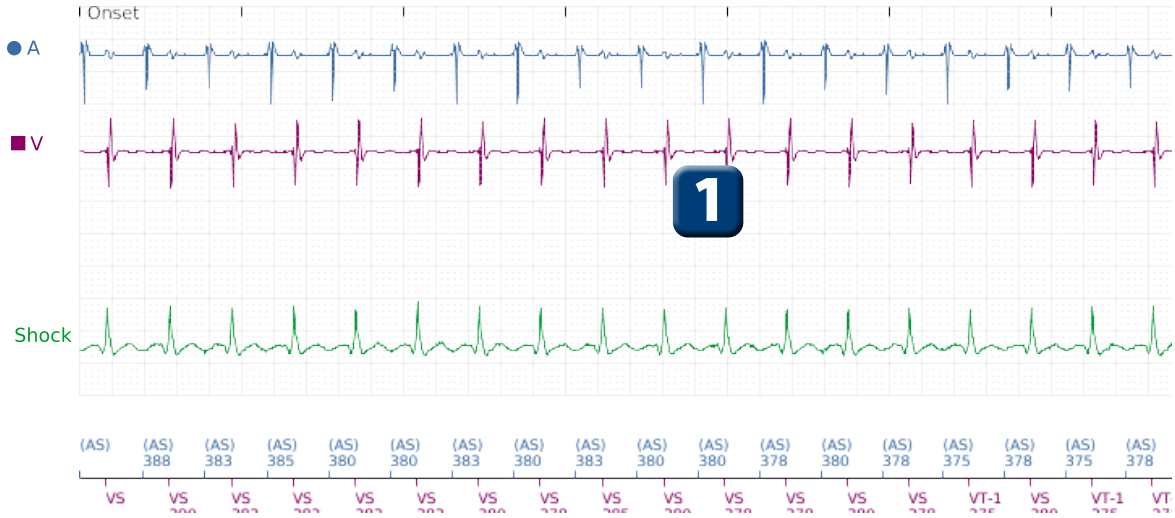
Elapsed Time	00:00:12

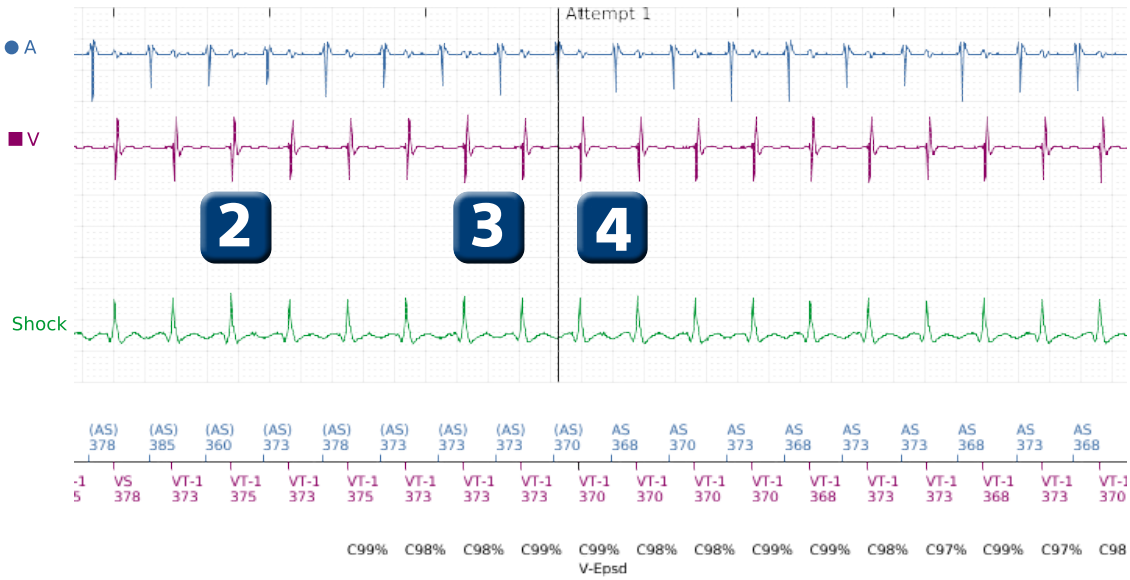
Attempt Information

Tachy therapy is programmed off.

Event Ended 00:00:23

EGM displayed at 25mm per second




Attempt 1
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VS 378 VT-1 373 VT-1 375 VT-1 373 VT-1 375 VT-1 373 VT-1 373 VT-1 373 VT-1 370 VT-1 370 VT-1 370 VT-1 370 VT-1 368 VT-1 373 VT-1 373 VT-1 368 VT-1 373 VT-1 370
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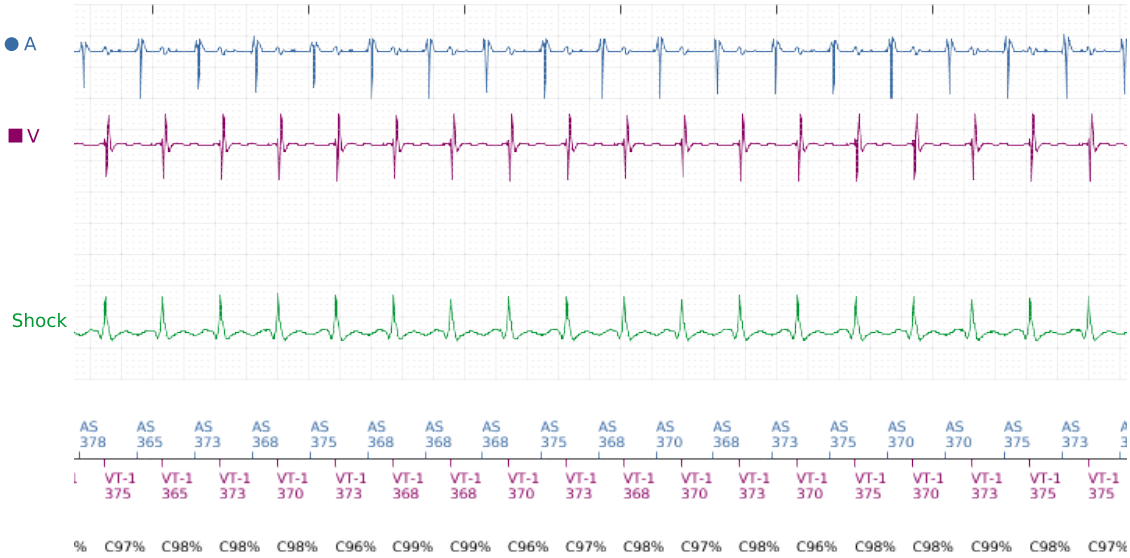
V-Epsd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VT-1 375 VT-1 365 VT-1 373 VT-1 370 VT-1 373 VT-1 368 VT-1 368 VT-1 370 VT-1 373 VT-1 368 VT-1 370 VT-1 373 VT-1 370 VT-1 375 VT-1 370 VT-1 373 VT-1 375 VT-1 375
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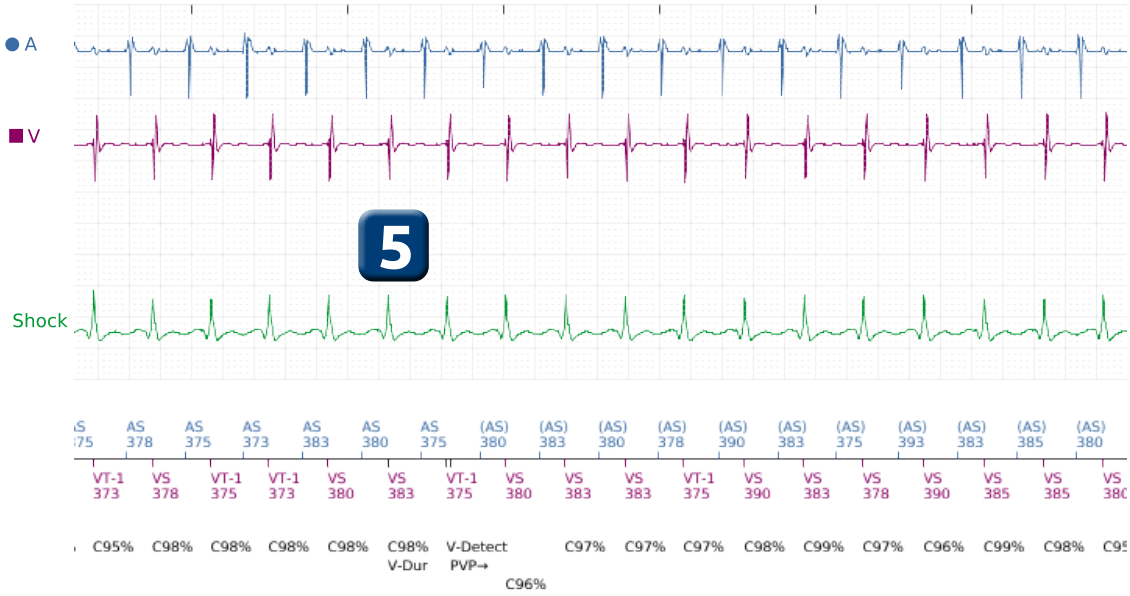
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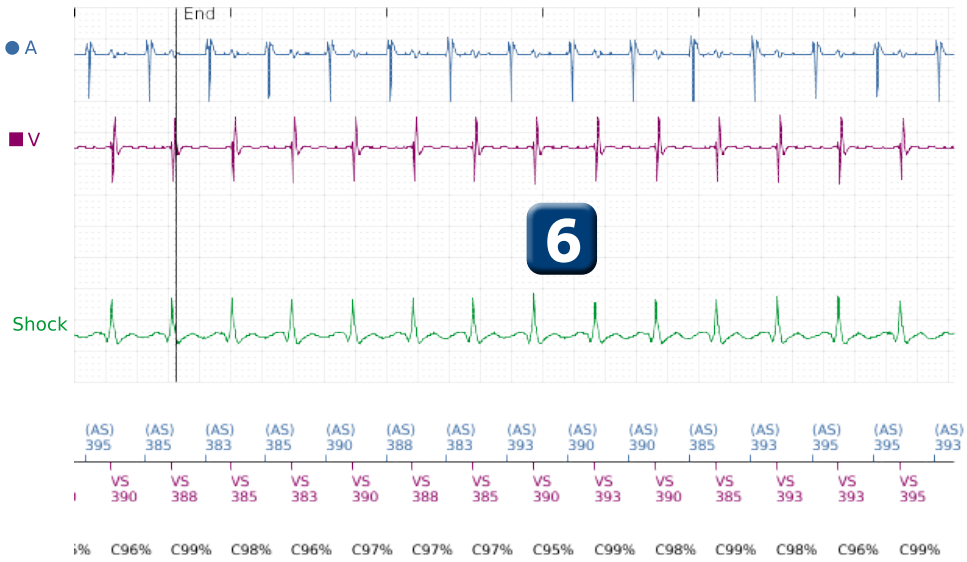
VT-1 373 VS 378 VT-1 375 VT-1 373 VS 380 VS 383 VT-1 375 VS 380 VS 383 VS 383 VT-1 375 VS 390 VS 383 VS 378 VS 390 VS 385 VS 385
C95% C98% C98% C98% C98% C98% V-Dur V-Detect PVP→ C96% C97% C97% C97% C98% C99% C97% C96% C99% C98%


End
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Shock
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VS 390 VS 388 VS 385 VS 383 VS 390 VS 388 VS 385 VS 390 VS 393 VS 390 VS 385 VS 393 VS 393 VS 395
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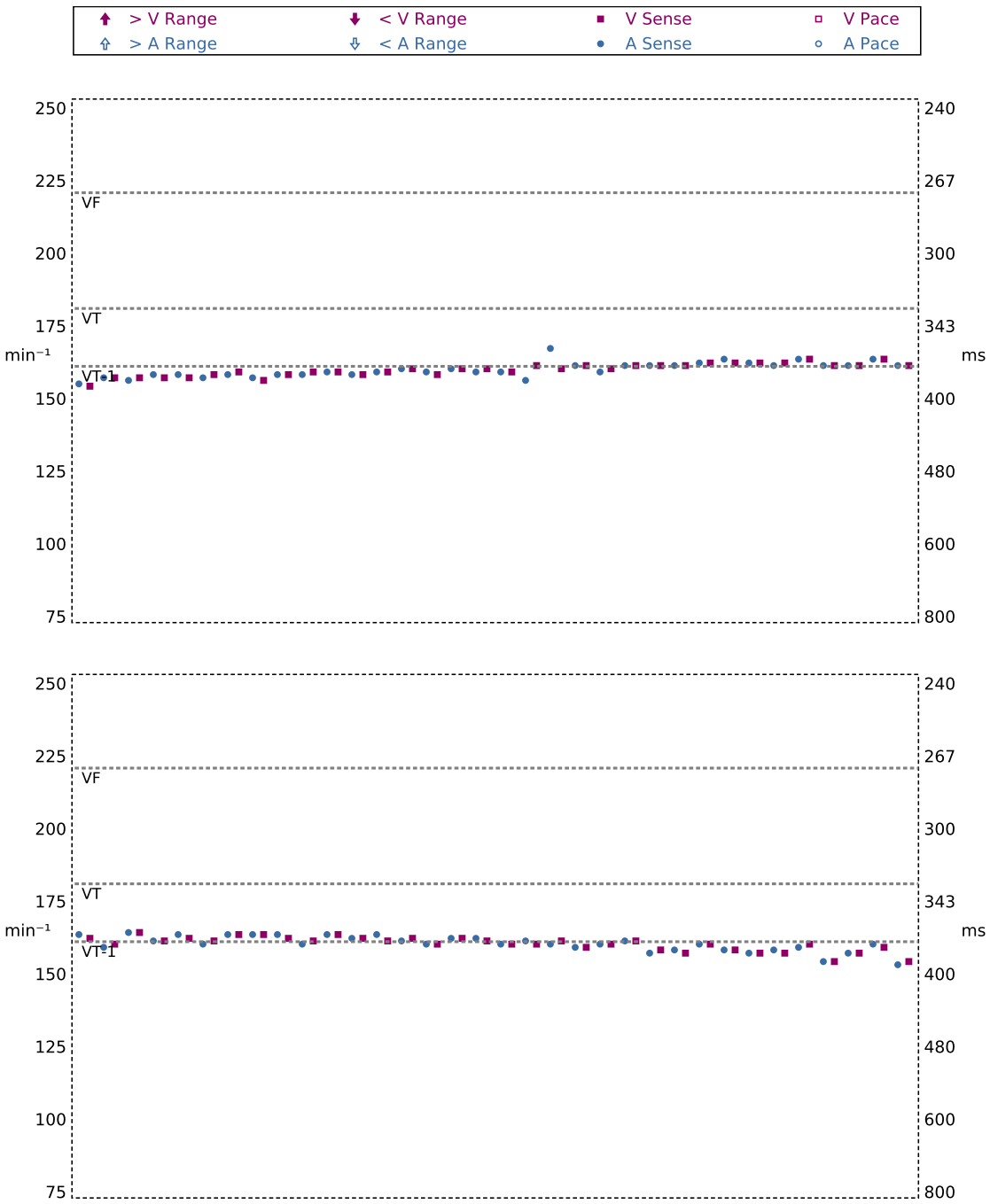

> V Range
< V Range
V Sense
V Pace
> A Range
< A Range
A Sense
A Pace
250
225
200
175
150
125
100
75
min⁻¹
VF
VT
VT-1
240
267
300
343
400
480
600
800
ms

Points to remember

- this trace corresponds to a sinus tachycardia that is well discriminated by the device; the presence of correlated vectors, a 1/1 A/V relationship and a stable rhythm are suggestive of possible sinus tachycardia or an atrial tachycardia/atrial flutter; progressive acceleration then deceleration favor sinus tachycardia; even if discrimination is correct and the device has correctly diagnosed supra-ventricular tachycardia, in this active patient implanted for primary prevention with no previous episodes of ventricular arrhythmia, it is probably acceptable to raise the VT detection zone to avoid overlap between physiological sinus rates and therapy detection zones.
- in this patient, the Rhythm ID and «Discrimination atrial tachyarrhythmia» discriminants are programmed "On»; the device proceeds in several stages
- step 1: V>A criterion; if the ventricular rate is considered higher than the atrial rate a diagnosis of VT is made without reference to other discriminants (morphology, stability, AF, etc.); this criterion enables correct discrimination of the majority of VTs presenting with atrioventricular dissociation.
- step 2: if the ventricular rate is not considered higher than the atrial rate, the analysis continues with the morphology criterion; if at least 3 out of 10 ventricular cycles are correlated (identical operation to that described for single-chamber), the tachycardia is considered supraventricular and therapies are inhibited ; when this criterion functions correctly (threshold adapted to the patient, satisfactory signal quality), it enables the majority of supraventricular tachycardias (sinus tachycardia, AF, flutter, intra-nodal reentries, orthodromic tachycardias) to be correctly discriminated; the morphology criterion will be misled (diagnosis of VT when it's a SVT) in the presence of an SVT with aberrant conduction, or in the presence of an antidromic tachycardia conducted over an accessory pathway (anecdotal diagnoses in patients implanted with a defibrillator).

9 Dual-chamber discrimination and atrial tachycardia

Patient

- 66-year-old man with a dual chamber defibrillator for ischemic cardiomyopathy

Summary

- episode detected in VT zone at 165 beats/minute
- Rhythm ID discrimination
- criterion V>A : False
- Rhythm ID correlated: True

EGM layout

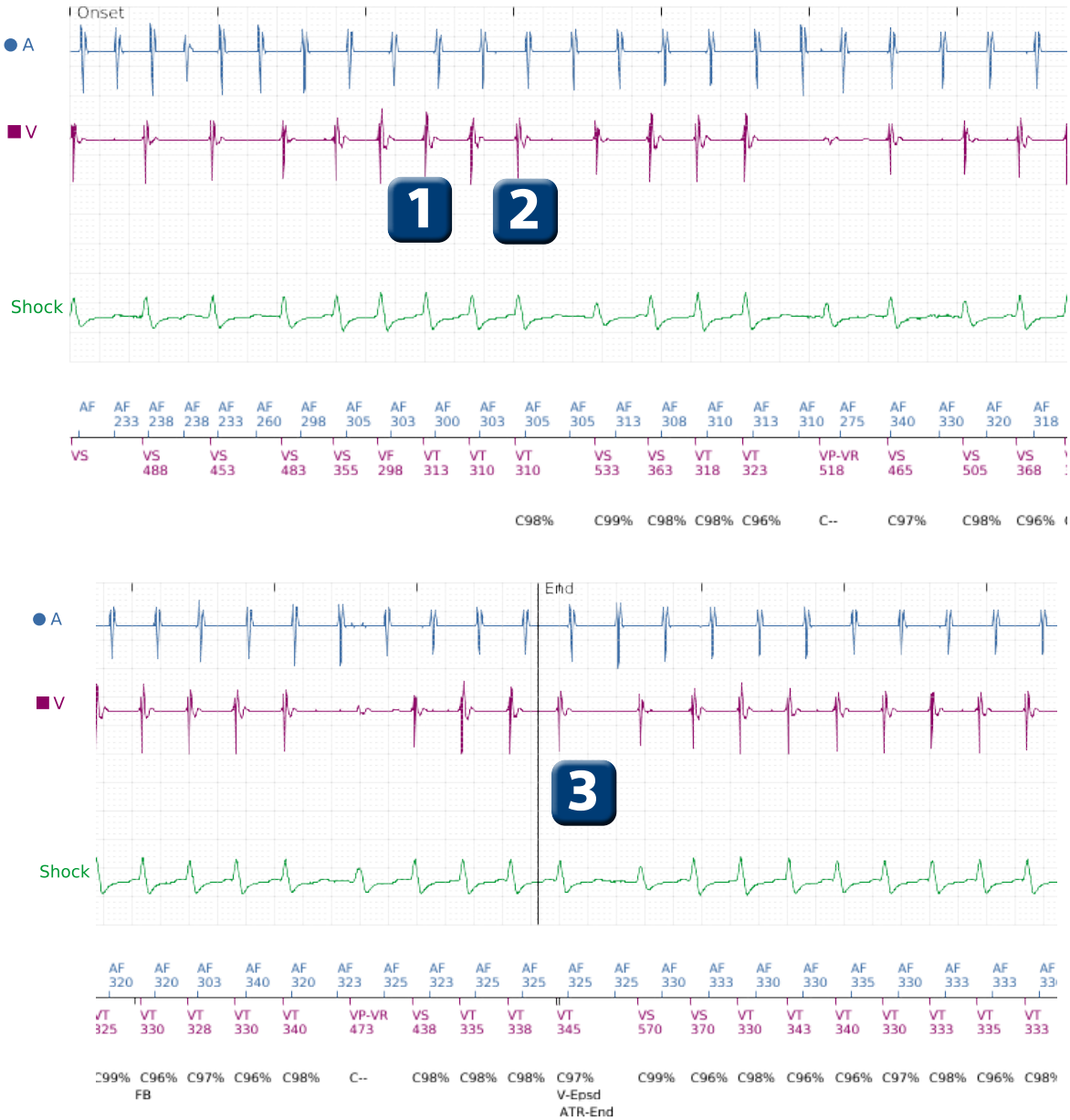
1. probable atrial tachycardia with variable conduction; alternating VS and VT cycles
2. correlated ventricular complexes (percentage exceeding the programmed threshold value of 94%)
3. after 8 out of 10 cycles in VT zone: V-Epsd marker
4. end of duration; discrimination is in favor of SVT (RID+); in fact, for at least 3 beats/10 (rolling window), the vector is correlated with the reference vector (the last 10 ventricular complexes before the end of duration are correlated).
5. cycle-by-cycle morphology analysis continues; the rate slows down and cycles are classified as VS; on this cycle, the 6/10 criterion for VT is no longer satisfied.

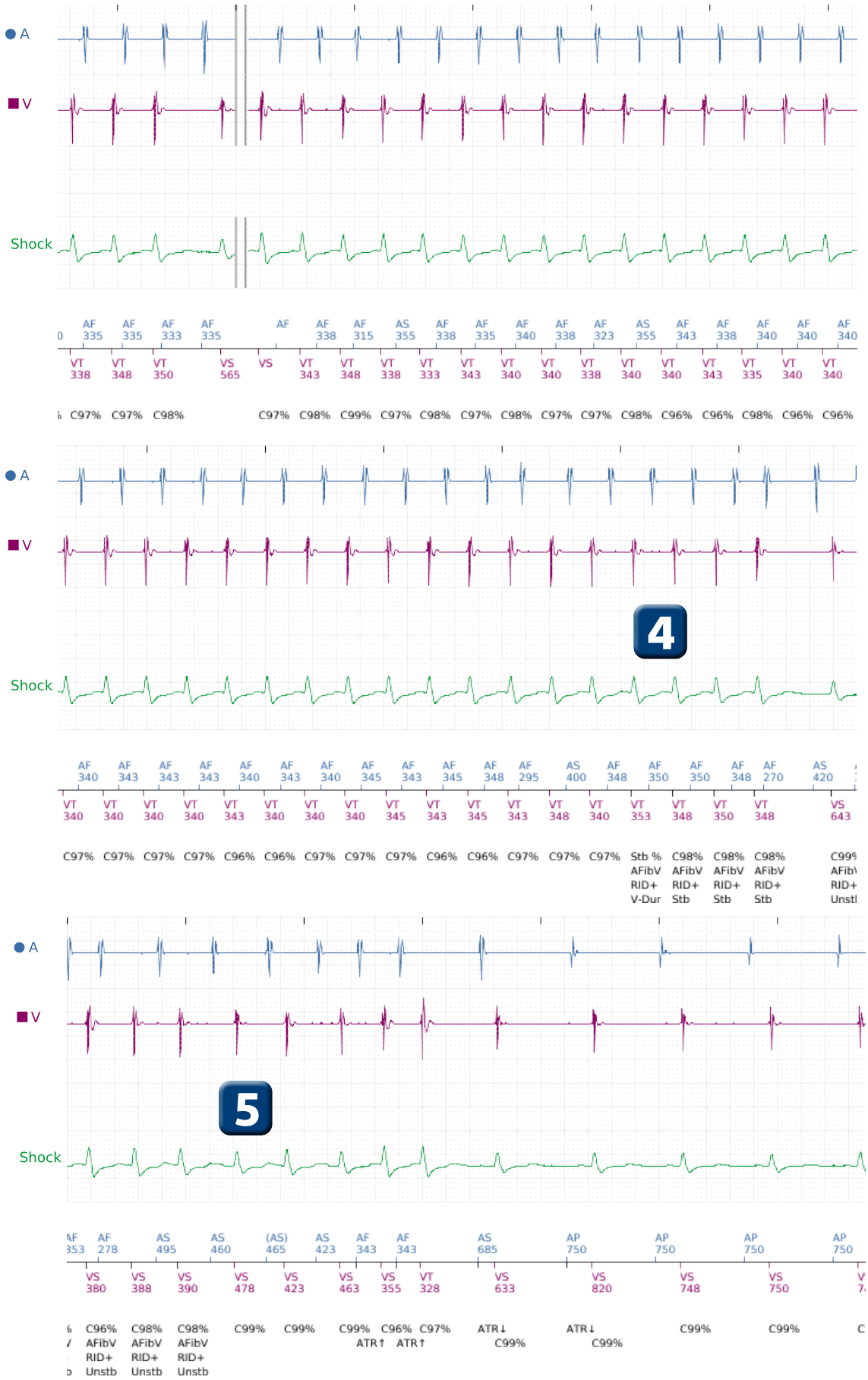
V-61: 09 Nov 2021 22:16, VT, A Rate: 185 min^{-1}, V Rate: 165 min^{-1}

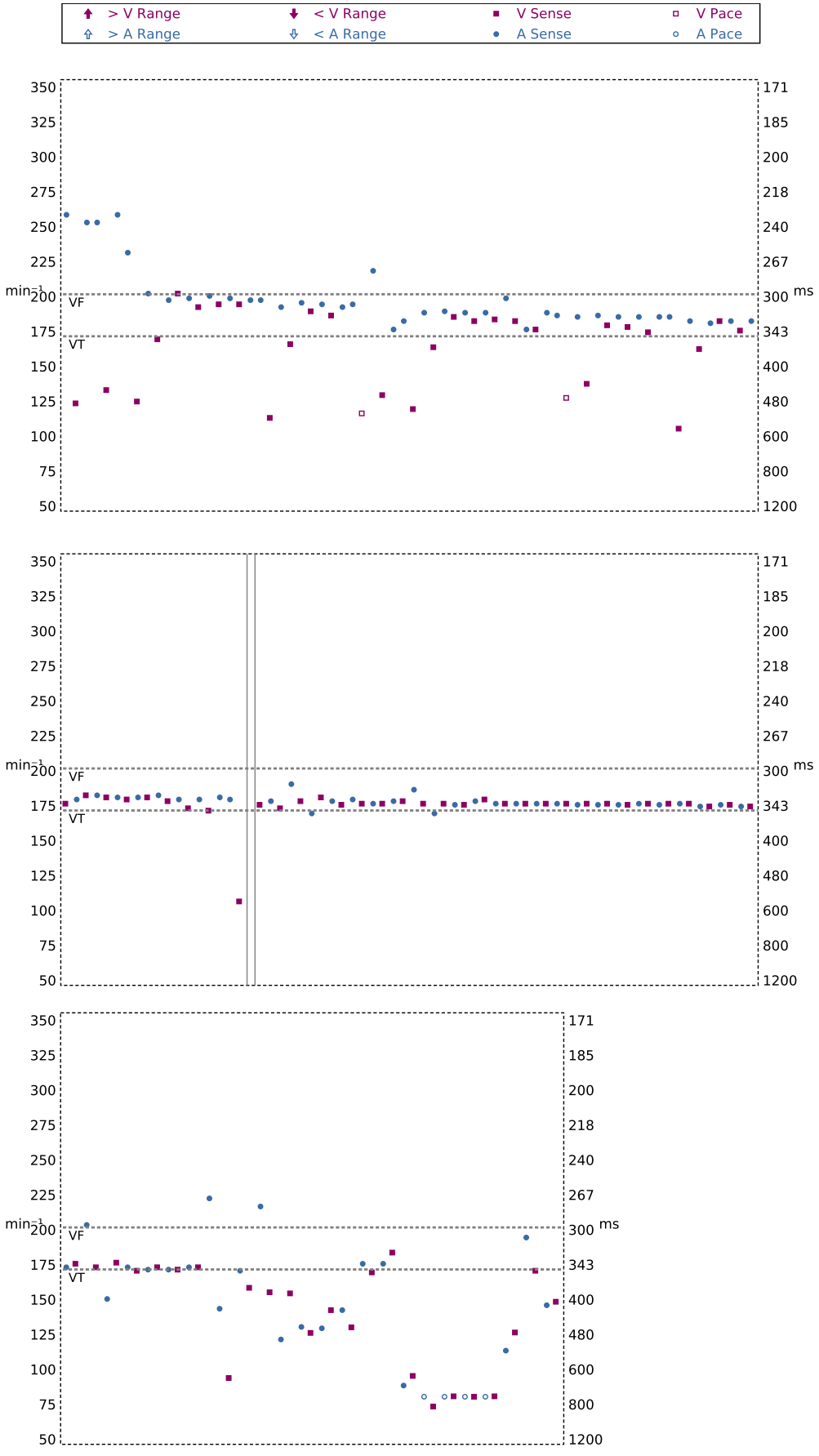
Detail

VT Event Onset		
Avg A Rate	185 min^{-1}	
Avg V Rate	165 min^{-1}	
Detection	Rhythm ID	
Template	09 Nov 2021 21:08	
RhythmMatch™ Threshold	94 %	
At Inhibit RhythmMatch™	97 %	
Event Ended		00:00:29

EGM displayed at 25mm per second

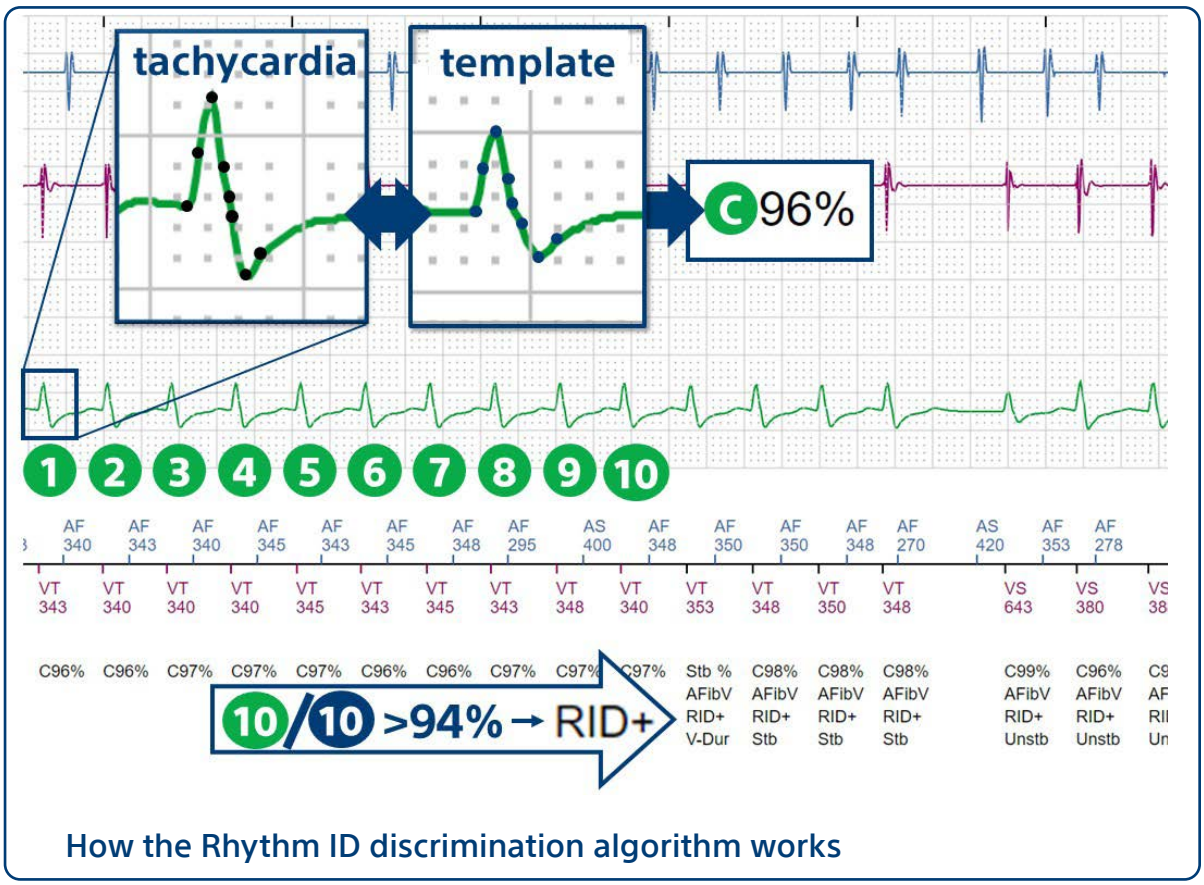



A
V
Shock
4
5


> V Range
< V Range
V Sense
V Pace
> A Range
< A Range
A Sense
A Pace
min⁻¹
ms
VF
VT
350
325
300
275
250
225
200
175
150
125
100
75
50
171
185
200
218
240
267
300
343
400
480
600
800
1200

Points to remember

- this trace corresponds to an episode of atrial tachycardia correctly discriminated by the device on the basis of the Rhythm ID algorithm; first stage, V>A: false; second stage, at least 3 out of 10 correlated ventricular cycles: true (RID+); diagnosis of SVT and continuation of cycle-by-cycle analysis with verification that the V>A criterion is not satisfied and that the number of correlated cycles (value greater than the programmed threshold) remains sufficient.
- atrial tachycardias/flutter 1/1 are impossible to discriminate with an algorithm based on abrupt onset (often present like in VT) and stability (stable rhythm like in VT); the Rhythm ID option is therefore clearly preferred in patients with this type of arrhythmia, provided this discriminant works properly (good signal quality, appropriately set threshold)



How the Rhythm ID discrimination algorithm works

10 Dual-chamber discrimination and dual tachycardia

Patient

- 59-year-old man; mitral valve cardiomyopathy with reduced ejection fraction; implanted with a dual-chamber defibrillator

Summary

- episode diagnosed as dual tachycardia by defibrillator with AF and VT
- A>V but stable rhythm and discordant vectors between tachycardia and the reference vector

EGM layout

1. AF with relatively rapid and irregular atrioventricular conduction
2. sudden acceleration of ventricular rhythm with change in ventricular electrogram morphology; rhythm becomes regular
3. at the third consecutive cycle in VT zone, initiation of arrhythmia episode detection; from this interval onwards, each atrial interval is classified as below or above the atrial fibrillation threshold (in this patient, threshold set at 170 beats/minute, nominal value); it is also from this cycle onwards (5 cycles before the episode marker) that stability measurement begins; the mean variance is calculated over these 5 intervals (4 variances)
4. after 8 consecutive VT cycles, V-Epsd marker
5. from this cycle, 10 cycles remain until the V-Detect marker is reached; vector correlation analysis is performed over these 10 cycles.
6. at the end of the duration, diagnosis of dual tachycardia and decision to treat: AF (initially at least 6 out of 10 rapid atrial intervals, then at least 4/10 rapid intervals in a rolling window), stable rhythm (measured variability < programmed stability threshold) without

correlation between morphology in tachycardia and reference morphology (for less than 3 beats/10, the vector correlates with the reference vector).

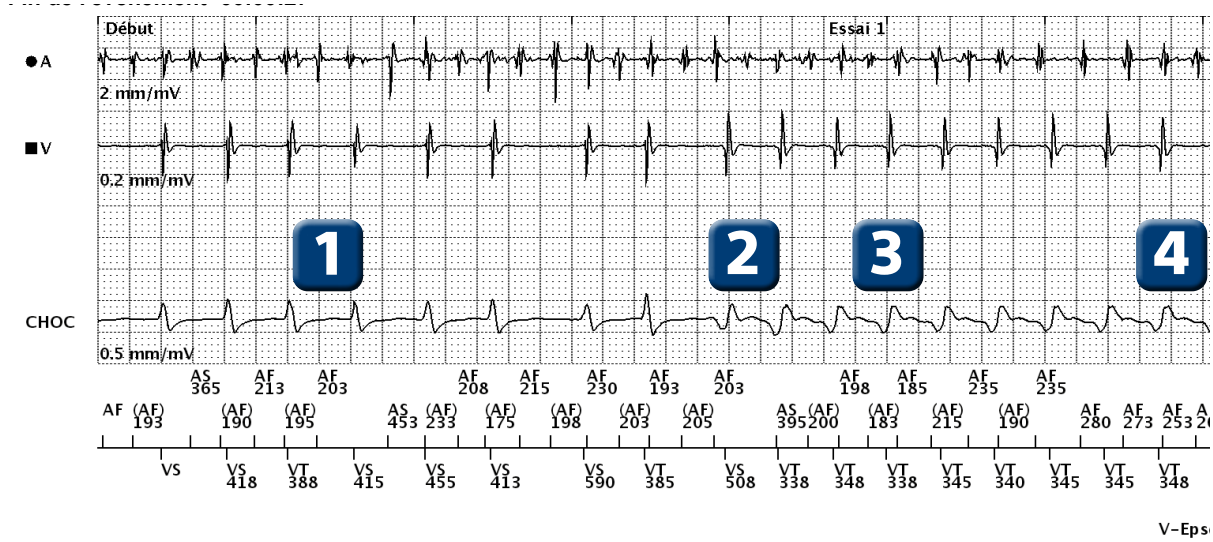
7 ATP burst (burst of 10 complexes)

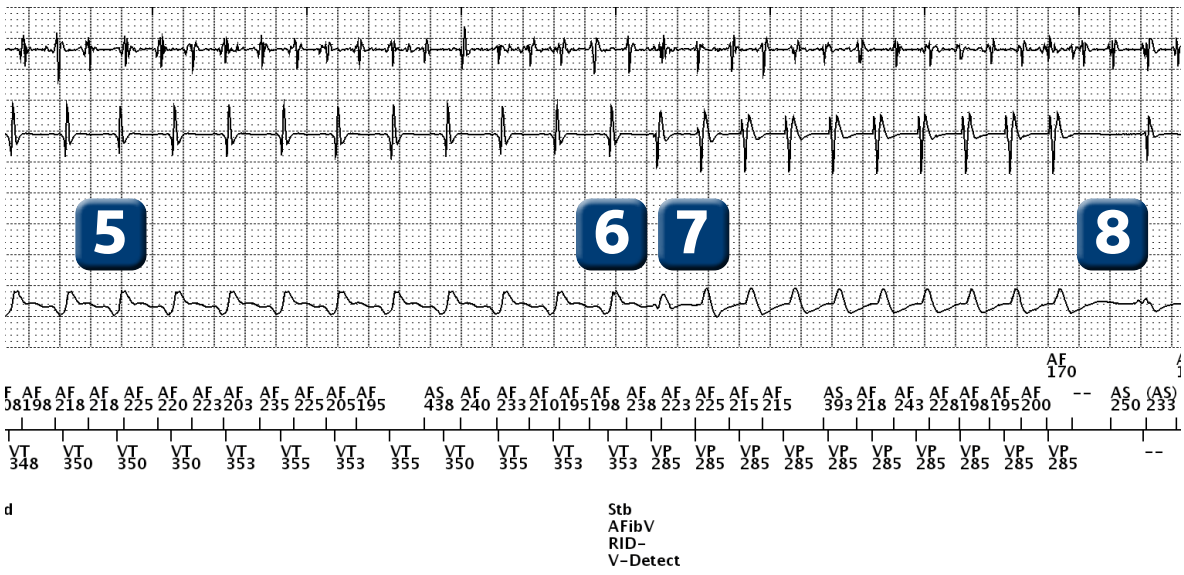
8 probable burst failure and ongoing dual tachycardia

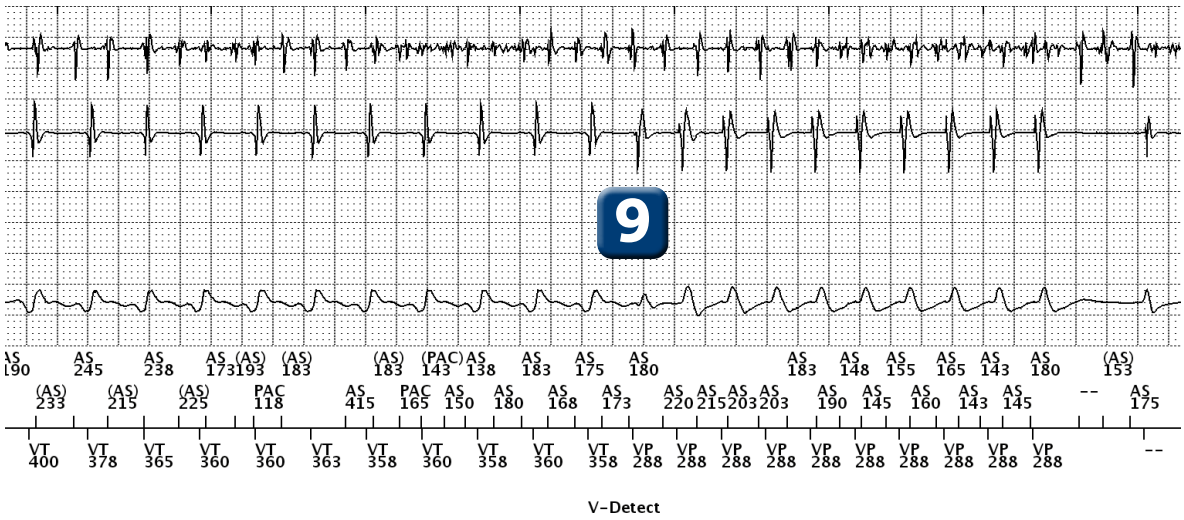
9 confirmation of persistent tachycardia based solely on a heart rate criteria (V-Detect). No discrimination is applied post-ATP

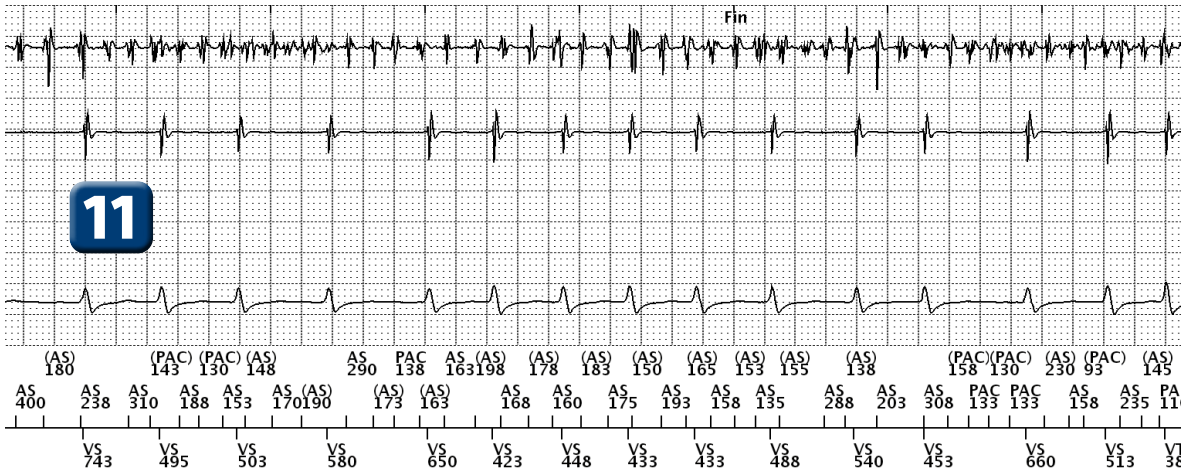
10 second burst

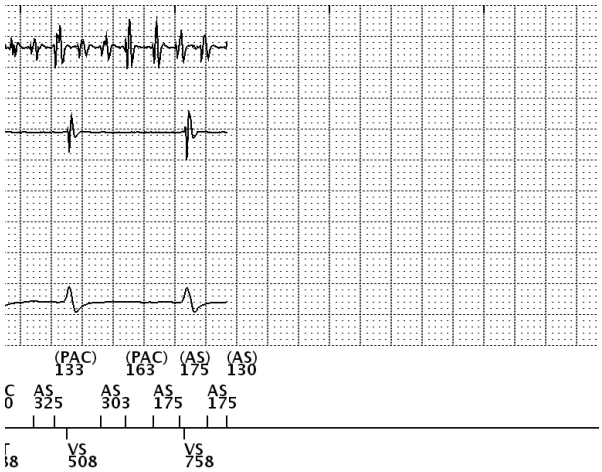
11 effective burst and termination of ventricular arrhythmia





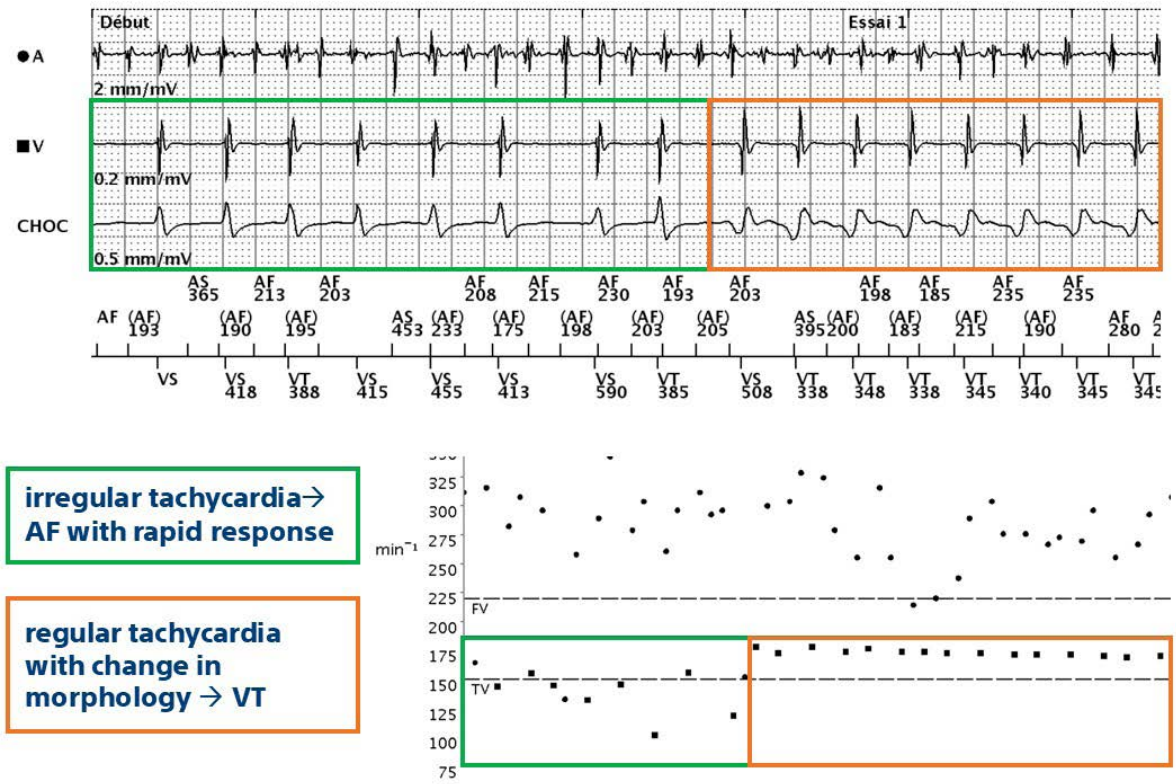

9
V-Detect


Fin
11



Points to remember

- this trace shows the value of coupling discriminators for the diagnosis of complex tachycardias such as dual tachycardias; discrimination is performed in stages
- stage 1, V>A : False
- stage 2, at least 3 ventricular cycles out of 10 correlated: false (RID-)
- the analysis continues (step 3) with an analysis of stability and a search for AF
- the AF rate threshold analysis looks for the presence of a fast atrial rhythm, by comparing the various atrial intervals against a programmed threshold (A Fib rate threshold); the atrial analysis begins when ventricular tachyarrhythmia detection is initialized; each atrial interval is classified as either faster or slower than the A Fib rate threshold; when at least 6 of the last 10 intervals are considered to be faster than the A Fib rate threshold, the device declares that AF is present; this parameter can only be programmed in conjunction with stability
- stability analysis is performed by measuring the degree of variability in RR intervals during tachycardia; the differences between ventricular cycles, as well as an average difference, are calculated throughout the Duration; when the Duration expires, rhythm stability is assessed by comparing the current average difference with the programmed Stability and “Shock if unstable” thresholds; if the average difference is greater than the programmed thresholds, the rhythm is declared unstable; independent thresholds are available for the Stability (inhibitory) and “ Shock if unstable” functions
- the idea behind linking the stability and AFib rate threshold criteria is to treat stable rhythms and unstable rhythms without AF (atrial rate < AFib rate threshold), but to inhibit in the presence of an unstable rhythm with atrial rate > AFib frequency threshold (suspicion of conducted AF).
- in this example, the device finds a diagnosis of AF with a stable rhythm (diagnosis of dual tachycardia) and therapies are delivered



This tracing shows a characteristic appearance of dual tachycardia (AF + VT): atrial activity is rapid and polymorphic (cycles correctly classified as AF); the ventricular channel shows abrupt acceleration with a regular, monomorphic tachycardia with a clear change in signal morphology on the shock channel (VT); the device diagnoses double tachycardia (V>A: False, RID-, AF, stable rhythm) and delivers therapies.

11 Dual-chamber discrimination and AF with aberrant conduction

Patient

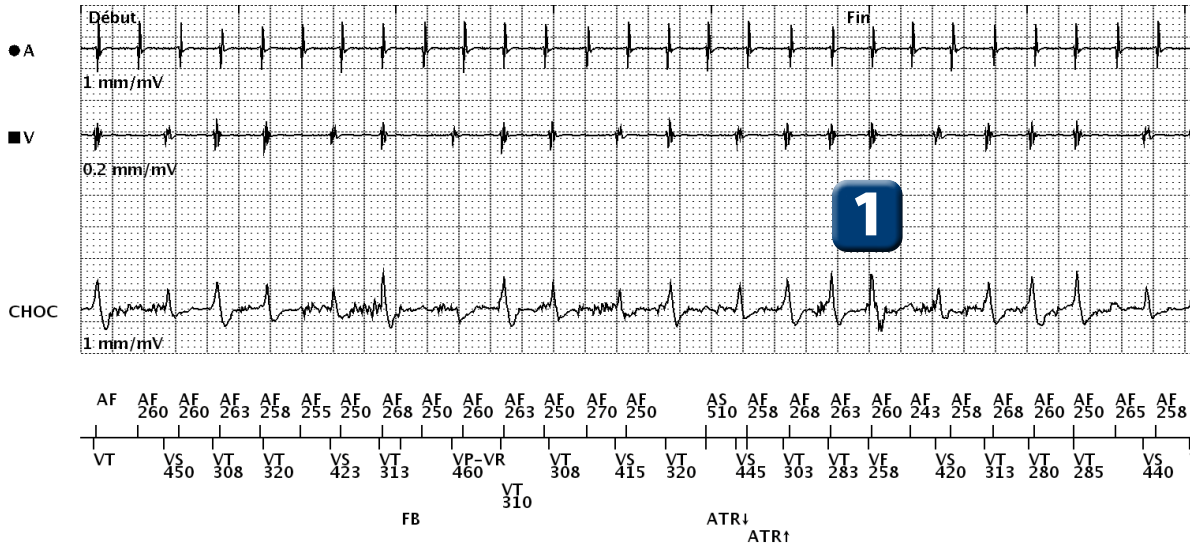
- 65-year-old male with severe ischemic cardiomyopathy; implanted with a dual-chamber defibrillator for primary prevention.

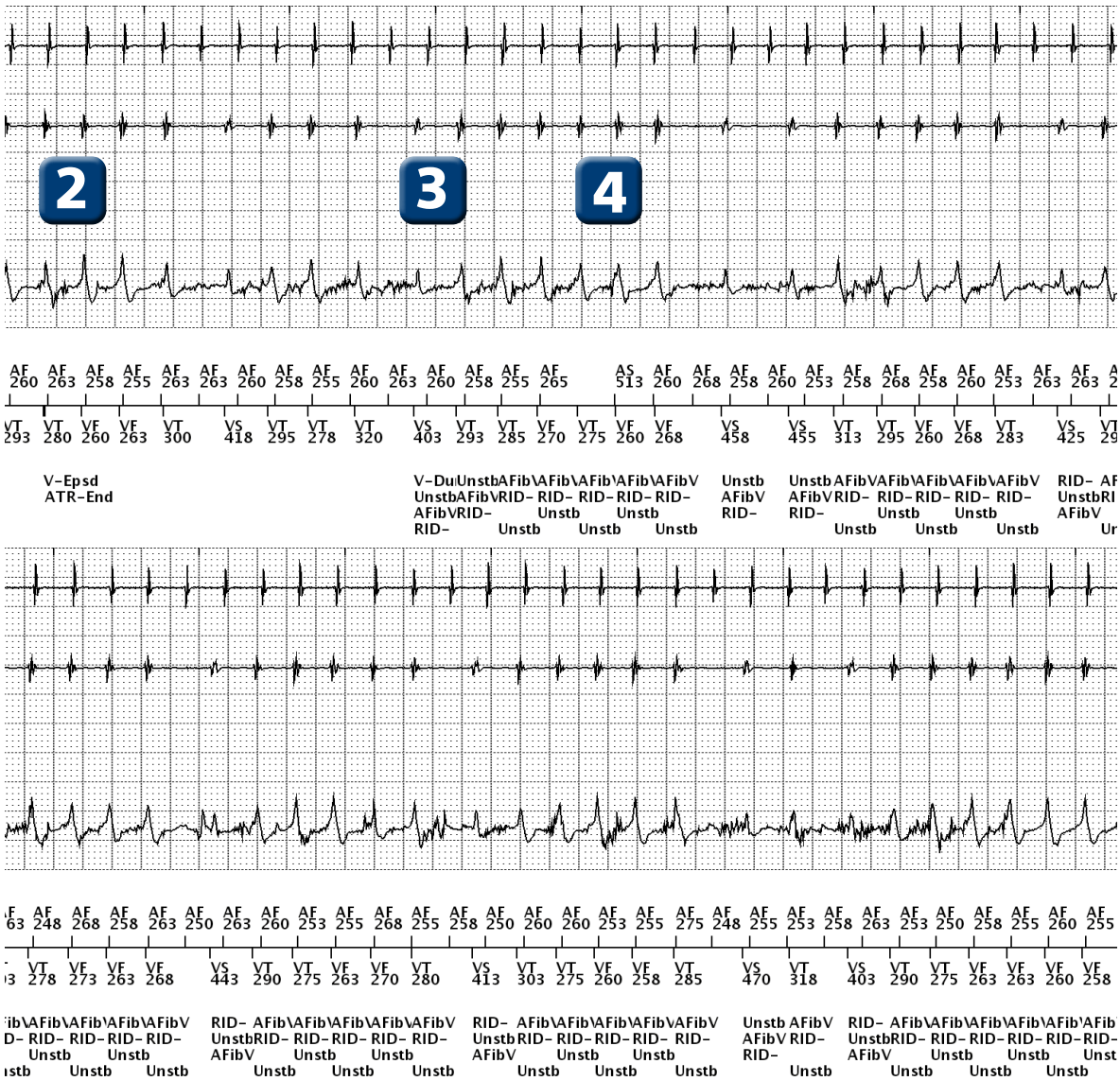
Summary

- episode diagnosed in the VT zone
- A>V and rhythm ID discrimination

EGM layout

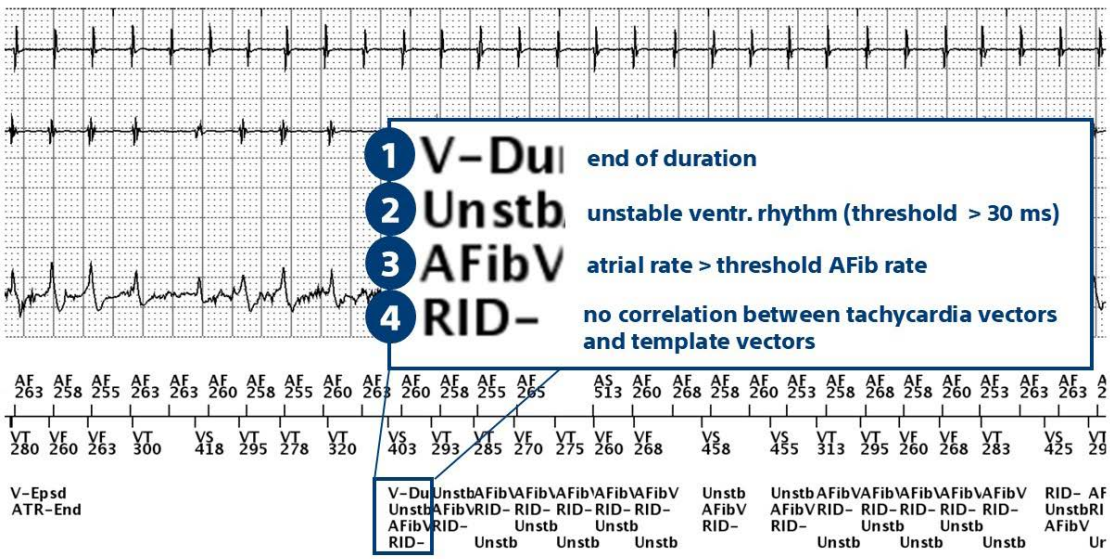
1. rapid atrial activity (probable atrial tachycardia) with rapid and variable atrio-ventricular conduction with alternating VS, VT then VF cycles
2. criterion 8/10 met (V-Epsd)
3. at the end of the duration, decision not to treat in the presence of AF (atrial rate > A Fib rate threshold), unstable ventricular rhythm (stability value > programmed threshold of 30 ms) with absence of correlation between tachycardia vectors and reference vector (less than 3 cycles/10 correlated; note that cycles classified as VF are systematically considered uncorrelated); electrogram analysis shows variability in the appearance of ventricular electrograms on the shock channel, with widening on the shortest cycles
4. continuation of cycle-by-cycle analysis with no change in diagnosis (aberrantly conducted AF)


Début
Fin
●A
1 mm/mV
■V
0.2 mm/mV
CHOC
1 mm/mV
1
AF AF AF AF AF AF AF AF AF AF AF AF AF AF AS AF AF AF AF AF AF AF AF AF AF AF
260 260 263 258 255 250 268 250 260 263 250 270 250 510 258 268 263 260 243 258 268 260 250 265 258
VT VS VT VT VS VT VP-VR VT VS VT VS VT VT VF VS VT VT VT VS
450 308 320 423 313 460 308 415 320 445 303 283 258 420 313 280 285 440
VT
310
FB
ATR↓
ATR↑


2
3
4
AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AS AF AF AF AF AF AF AF AF AF AF AF
260 263 258 255 263 263 260 258 255 260 263 260 258 255 265 513 260 268 258 260 253 258 268 258 260 253 263 263
VT VT VF VF VT VS VT VT VT VS VT VT VF VT VF VF VS VS VT VT VF VF VT VS
293 280 260 263 300 418 295 278 320 403 293 285 270 275 260 268 458 455 313 295 260 268 283 425
V-Epsd
ATR-End
V-Du UnstbAFib\RID- AFib\RID- AFib\RID- AFib\RID- AFibV RID-
Unstb Unstb Unstb Unstb
Unstb AFibV RID-
Unstb AFibV RID- AFib\RID- AFib\RID- AFib\RID- AFib\RID- AFibV RID-
Unstb Unstb Unstb Unstb
RID- AF UnstbRI AFibV
Ur
AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF
248 268 258 263 250 263 260 253 255 268 255 258 250 260 260 253 255 275 248 255 253 258 263 253 250 258 255 260 255
VT VF VF VF VS VT VT VF VF VT VS VT VT VF VF VT VS VT VS VT VT VF VF VF VF
278 273 263 268 443 290 275 263 270 280 413 303 275 260 258 285 470 318 403 290 275 263 263 260 258
AFib\RID- AFib\RID- AFib\RID- AFibV RID- AFib\RID- AFib\RID- AFib\RID- AFib\RID- AFibV RID- AFib\RID- AFib\RID- AFib\RID- AFib\RID- AFibV Unstb AFibV RID- AFib\RID- AFib\RID- AFib\RID- AFib\RID- AFibV
Unstb Unstb

Points to remember

- dual tachycardias and AF with aberrant conduction are probably the most difficult tachycardias to discriminate for a dual-chamber defibrillator; in fact, the V>A criterion does not allow a decision to be made, since in both cases the atrial rhythm is faster than the ventricular rhythm; in both cases, there is also no correlation between the vectors during tachycardia and the reference vector.
- when morphology analysis is combined with stability and the search for AF, stability determines the diagnosis when the vectors are not correlated and the atrial rate > A Fib rate threshold: if the rhythm is stable, the device diagnoses dual tachycardia and delivers therapies; if the rhythm is unstable, it diagnoses AF with aberrant conduction and inhibits therapies (as in this example)



This tracing shows a characteristic appearance of atrial tachycardia with aberrant conduction: atrial activity is rapid and regular (cycles correctly classified as AF); the ventricular channel shows an irregular rhythm with a variable appearance of QRS complexes on the shock channel (narrow QRS on long cycles, wide QRS on rapid cycles); the device diagnoses AF with aberrant conduction (V>A: False, RID-, AF, unstable rhythm) and inhibits therapies.

12 Dual-chamber discrimination and discrimination error due to signal variability on the shock channel

Patient

- 49-year-old man; hypertrophic cardiomyopathy; implanted with an Autogen dual-chamber defibrillator

Summary

- tachycardia episode with atrial rate equal to ventricular rate (V>A False)
- initially, correlation of Rhythm ID: True; inhibition of therapies
- in a second step, Rhythm ID: False; AF: true + stable rhythm (threshold value set at 20 ms)
- all VT zone therapies are delivered (ATP + 6 shocks)

EGM layout

1 regular tachycardia 1/1 (AS-VS)

2 acceleration of atrial cycles (cycles classified as AF) and ventricular cycles (cycles classified as VT)

3 after 8 consecutive VT cycles, V-Epsd marker; signal quality in the shock channel is variable (some cycles are considered correlated, others uncorrelated)

4 end of duration; for the device, the rhythm is stable with a diagnosis of AF; therapies are not delivered because RID+ (at least 3 correlated ventricular complexes out of 10).

5 cycle-by-cycle discrimination continues, still with RID+.

6 signal variability on the shock channel; RID- (less than 3 correlated cycles out of the last 10); stable rhythm with diagnosis of AF: suspicion of double tachycardia and first therapy is delivered.

7 redetection and new therapies; all therapies in the zone are then delivered

V-98: 20 Oct 2016 08:30, VT, A Rate: 170 min^{-1}, V Rate: 171 min^{-1}

Detail

VT Event Onset

Avg A Rate	170 min^{-1}
Avg V Rate	171 min^{-1}
Detection	Rhythm ID
Template	20 Oct 2016 04:05
RhythmMatch™ Threshold	94 %

At Inhibit

Stability	3 ms
V>A Rate	False
AFib	True
RhythmID Correlated	True
RhythmMatch™	97 %

At V-Detect

Avg A Rate	182 min^{-1}
Avg V Rate	183 min^{-1}
Rate Zone	VT
RhythmMatch™	92 %
SRD Met	(False, Off)
ATP Timeout	False

At V-Detect

Avg A Rate	192 min^{-1}
Avg V Rate	192 min^{-1}
Rate Zone	VT
ATP Timeout	False

At V-Detect

Avg A Rate	197 min^{-1}
Avg V Rate	197 min^{-1}
Rate Zone	VT
ATP Timeout	False

At V-Detect

Avg A Rate	199 min^{-1}
Avg V Rate	182 min^{-1}
Rate Zone	VT
Stability	12 ms
V>A Rate	False
AFib	True
SRD Met	(False, Off)
ATP Timeout	False

At V-Detect

Avg A Rate	72 min^{-1}
Avg V Rate	180 min^{-1}
Rate Zone	VT
V>A Rate	True
AFib	False
SRD Met	(False, Off)
ATP Timeout	False

At V-Detect

Avg A Rate	197 min^{-1}
Avg V Rate	176 min^{-1}
Rate Zone	VT
Stability	15 ms
V>A Rate	True
AFib	True
SRD Met	(False, Off)
ATP Timeout	False

At V-Detect

Avg A Rate	196 min^{-1}
Avg V Rate	197 min^{-1}
Rate Zone	VT
Stability	9 ms
V>A Rate	False
AFib	True
SRD Met	(False, Off)
ATP Timeout	False

At V-Detect

Avg A Rate	191 min^{-1}
Avg V Rate	189 min^{-1}
Rate Zone	VT
Stability	14 ms
V>A Rate	False
AFib	True
SRD Met	(False, Off)
ATP Timeout	False

At V-Detect

Avg A Rate	189 min^{-1}
Avg V Rate	189 min^{-1}
Rate Zone	VT
Stability	2 ms
V>A Rate	False
AFib	True
SRD Met	(False, Off)
ATP Timeout	False

Event Ended 00:03:48

Attempt 1, Burst V ATP

Elapsed Time	00:00:21
Inhibited Attempt	
ATP Information	
Number of Bursts	3

Attempt 2, Ramp V ATP

Elapsed Time	00:00:44
ATP Information	
Number of Bursts	3

Attempt 3, 41 J V Shock

Elapsed Time	00:01:07
Shock Information	
Charge Time	8.8 s
Lead Impedance	54 Ω
Lead Polarity	Initial

Attempt 4, 41 J V Shock

Elapsed Time	00:01:21
Shock Information	
Charge Time	6.9 s
Lead Impedance	55 Ω
Lead Polarity	Initial

Attempt 5, 41 J Max V Shock

Elapsed Time	00:01:33
Shock Information	
Charge Time	6.9 s

Attempt 6, 41 J Max V Shock

Elapsed Time	00:01:46
Shock Information	
Charge Time	6.9 s
Lead Impedance	56 Ω
Lead Polarity	Initial

Attempt 7, 41 J Max V Shock

Elapsed Time	00:01:58
Shock Information	
Charge Time	7.0 s
Lead Impedance	60 Ω
Lead Polarity	Initial

Attempt 8, 41 J Max V Shock

Elapsed Time	00:02:11
Shock Information	
Charge Time	7.0 s
Lead Impedance	58 Ω
Lead Polarity	Reversed

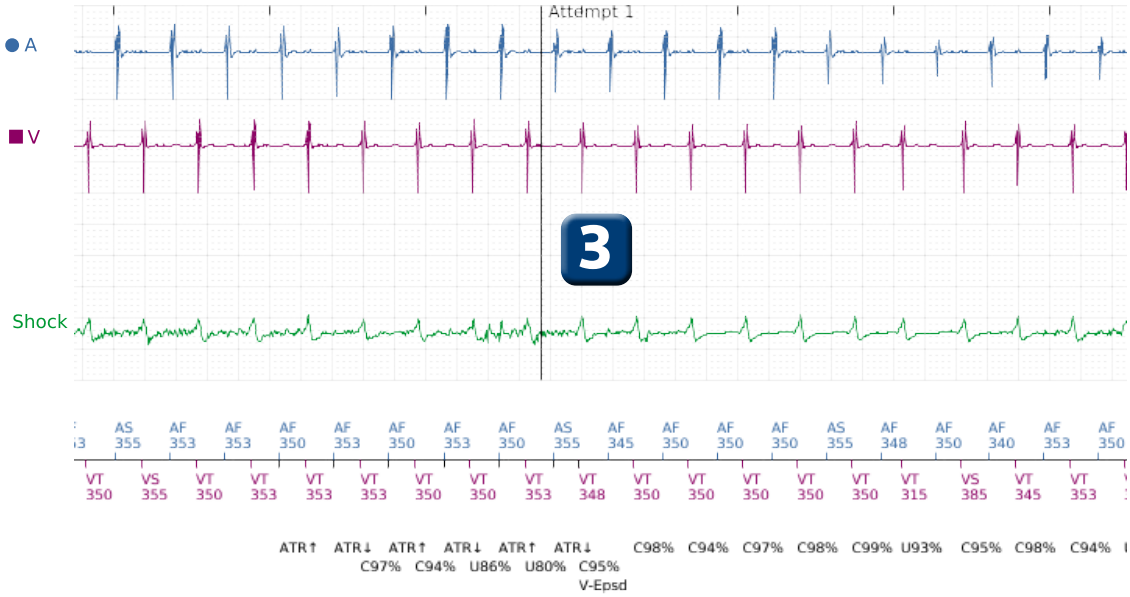
Attempt 9, Non Therapy V

Elapsed Time	00:02:28

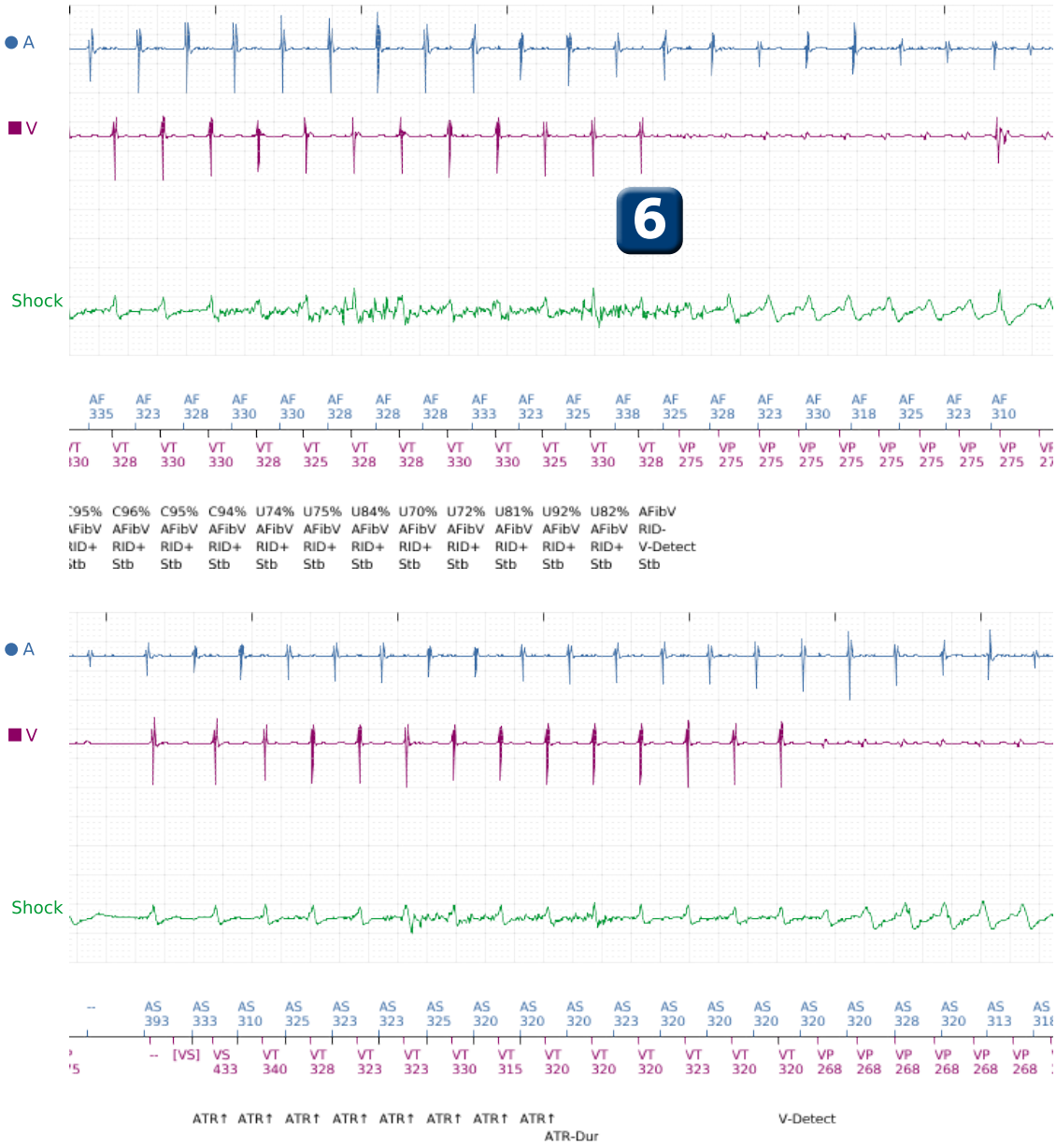
Attempt Information

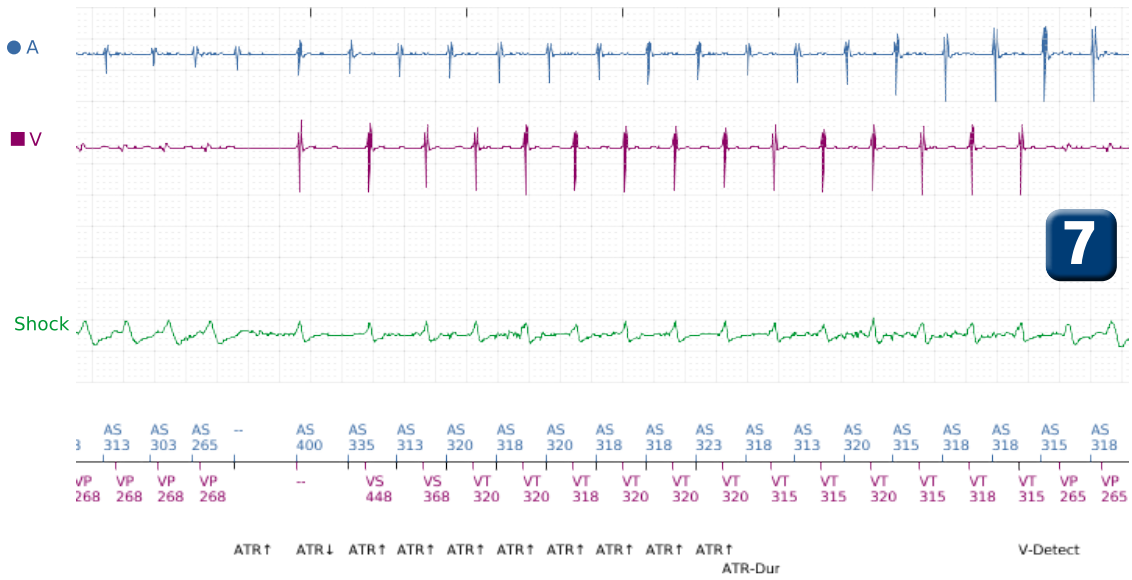
All programmed therapy has been delivered.

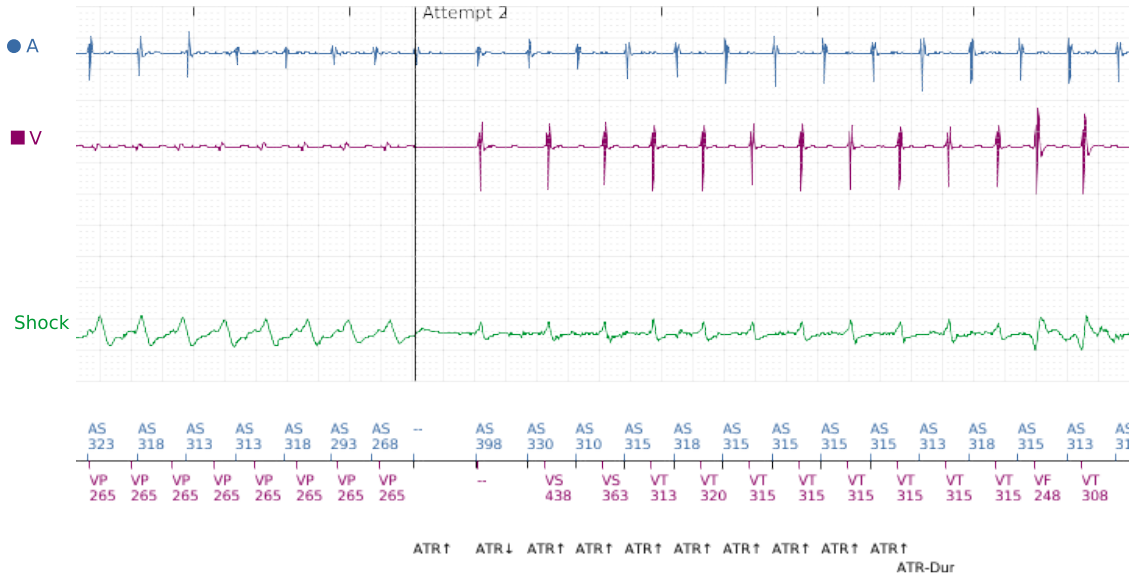

Onset
A
V
1
2
Shock
AS AS AS AS AS AS AS AS AS AS AS AS AS AS AS AS AS AS
368 365 363 365 363 360 360 360 360 365 355 363 355 355 355 355 355
VS VS VS VS VS VS VS VS VS VS VS VS VS VS VS VS VS VS VT VS
365 365 360 363 360 363 360 360 360 363 360 360 358 358 355 353 358


Attempt 1
A
V
3
Shock
AS AF AF AF AF AF AF AF AF AS AF AF AF AF AS AF AF AF AF AF
355 353 353 350 353 350 353 350 355 345 350 350 350 355 348 350 340 353 350
VT VS VT VT VT VT VT VT VT VT VT VT VT VT VT VT VS VT VT
350 355 350 353 353 353 350 350 353 348 350 350 350 350 350 315 385 345 353
ATR↑ ATR↓ ATR↑ ATR↓ ATR↑ ATR↓ C98% C94% C97% C98% C99% U93% C95% C98% C94%
C97% C94% U86% U80% C95%
V-Epsd

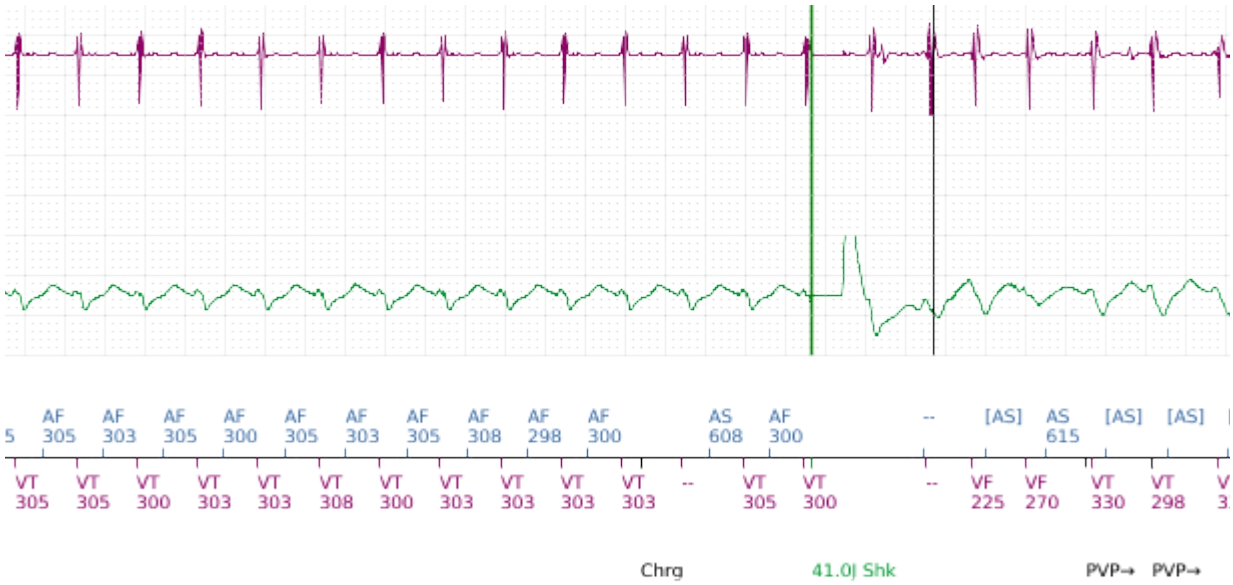

A
V
Shock
AF 343 AF 345 AF 350 AF 345 AF 340 AF 345 AF 343 AF 348 AF 340 AF 340 AF 343 AF 348 AF 338 AF 338 AF 343 AF 340 AF 338 AF 335 AF 338
VT 348 VT 348 VT 348 VT 345 VT 348 VT 343 VT 345 VT 340 VT 345 VT 343 VT 340 VT 340 VT 343 VT 343 VT 338 VT 343 VT 340 VT 338 VT 338 VT 335
U87% C94% C96% U68% U71% C96% C95% C95% U90% C97% C98% C95% C94% C97% C95% C97% C98% C94% C94% U87%
A
V
4 5
Shock
AF 335 AF 335 AF 343 AF 328 AF 335 AF 335 AF 333 AF 335 AF 333 AF 330 AF 333 AF 333 AF 335 AF 335 AF 330 AF 325 AF 330 AF 333 AF 330 AF 330
VT 335 VT 338 VT 333 VT 338 VT 335 VT 335 VT 333 VT 333 VT 335 VT 333 VT 333 VT 333 VT 330 VT 333 VT 333 VT 330 VT 338 VT 323 VT 330 VT 333
Stb% U93% U92% C98% C95% U90% U91% C97% C96% C97% U92% C95% C97% C96% C97% C97% C95% U89% C94% C96%
AFibV AFibV AFibV AFibV AFibV AFibV AFibV AFibV AFibV AFibV AFibV AFibV AFibV AFibV AFibV AFibV AFibV AFibV AFibV AFibV
RID+ RID+ RID+ RID+ RID+ RID+ RID+ RID+ RID+ RID+ RID+ RID+ RID+ RID+ RID+ RID+ RID+ RID+ RID+ RID+
V-Dur Stb Stb Stb Stb Stb Stb Stb Stb Stb Stb Stb Stb Stb Stb Stb Stb Stb Stb Stb

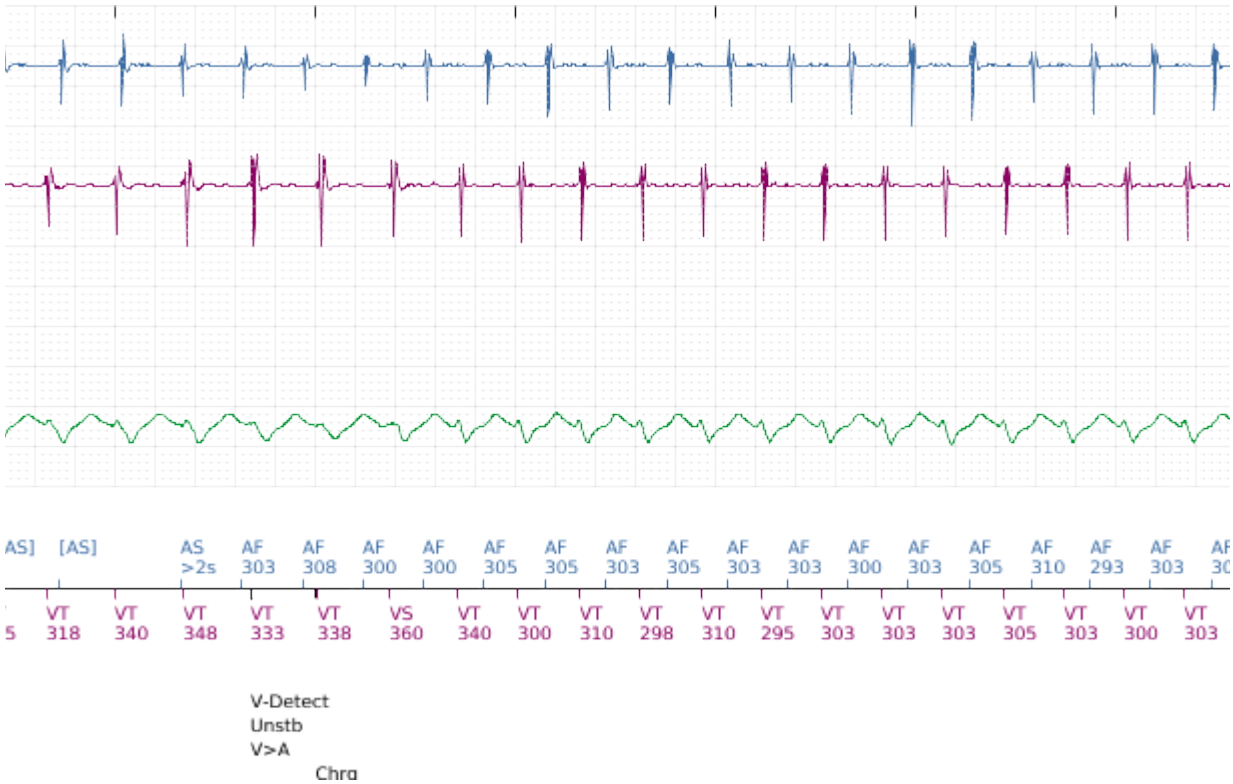

A
V
6
Shock
AF 335 AF 323 AF 328 AF 330 AF 330 AF 328 AF 328 AF 328 AF 333 AF 323 AF 325 AF 338 AF 325 AF 328 AF 323 AF 330 AF 318 AF 325 AF 323 AF 310
VT 328 VT 330 VT 330 VT 328 VT 325 VT 328 VT 328 VT 330 VT 330 VT 325 VT 330 VT 328 VP 275 VP 275 VP 275 VP 275 VP 275 VP 275 VP 275 VP 275 VP 275
C95% AFibV RID+ Stb
C96% AFibV RID+ Stb
C95% AFibV RID+ Stb
C94% AFibV RID+ Stb
U74% AFibV RID+ Stb
U75% AFibV RID+ Stb
U84% AFibV RID+ Stb
U70% AFibV RID+ Stb
U72% AFibV RID+ Stb
U81% AFibV RID+ Stb
U92% AFibV RID+ Stb
U82% AFibV RID+ Stb
AFibV RID- V-Detect Stb
A
V
Shock
-- AS 393 AS 333 AS 310 AS 325 AS 323 AS 323 AS 325 AS 320 AS 320 AS 320 AS 323 AS 320 AS 320 AS 320 AS 320 AS 320 AS 328 AS 320 AS 313
-- [VS] VS 433 VT 340 VT 328 VT 323 VT 323 VT 330 VT 315 VT 320 VT 320 VT 320 VT 323 VT 320 VT 320 VP 268 VP 268 VP 268 VP 268 VP 268 VP 268
ATR↑ ATR↑ ATR↑ ATR↑ ATR↑ ATR↑ ATR↑ ATR↑
ATR-Dur
V-Detect


A
V
7
Shock
AS 313 AS 303 AS 265 -- AS 400 AS 335 AS 313 AS 320 AS 318 AS 320 AS 318 AS 318 AS 323 AS 318 AS 313 AS 320 AS 315 AS 318 AS 318 AS 315 AS 318
VP 268 VP 268 VP 268 VP 268 -- VS 448 VS 368 VT 320 VT 320 VT 318 VT 320 VT 320 VT 320 VT 315 VT 315 VT 320 VT 315 VT 318 VT 315 VP 265 VP 265
ATR↑ ATR↓ ATR↑ ATR↑ ATR↑ ATR↑ ATR↑ ATR↑ ATR↑ ATR↑
ATR-Dur
V-Detect


Attempt 2
A
V
Shock
AS 323 AS 318 AS 313 AS 313 AS 318 AS 293 AS 268 -- AS 398 AS 330 AS 310 AS 315 AS 318 AS 315 AS 315 AS 315 AS 315 AS 313 AS 318 AS 315 AS 313
VP 265 VP 265 VP 265 VP 265 VP 265 VP 265 VP 265 VP 265 -- VS 438 VS 363 VT 313 VT 320 VT 315 VT 315 VT 315 VT 315 VT 315 VT 315 VF 248 VT 308
ATR↑ ATR↓ ATR↑ ATR↑ ATR↑ ATR↑ ATR↑ ATR↑ ATR↑ ATR↑
ATR-Dur

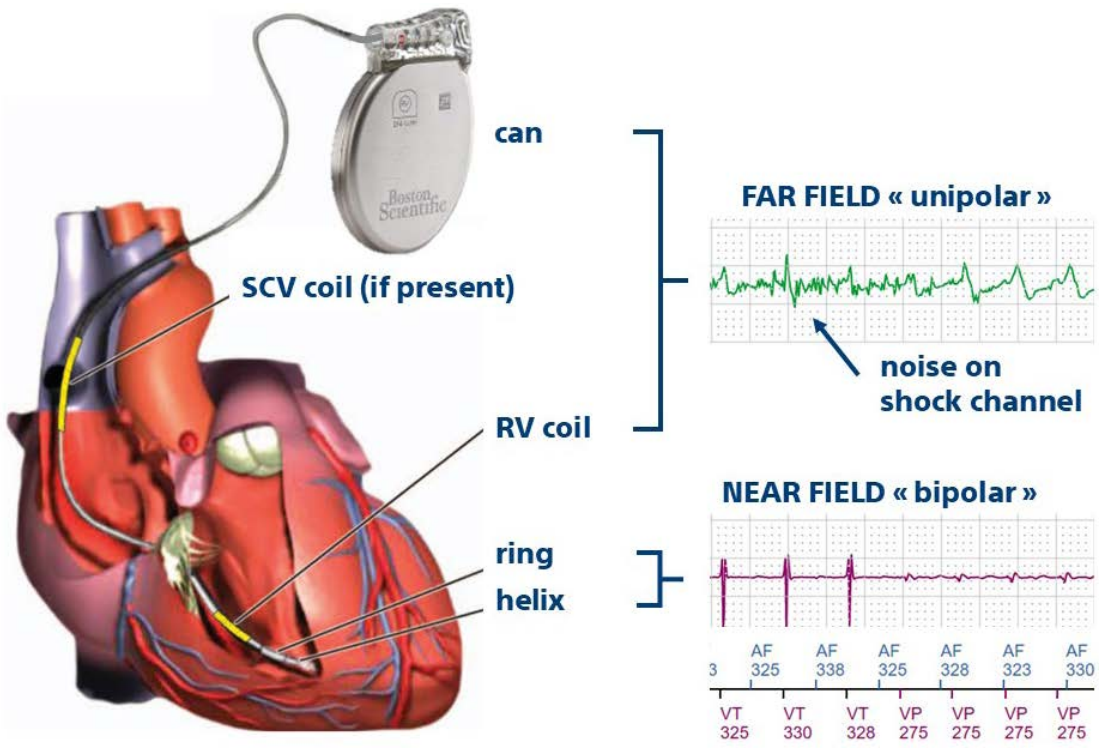
not whole episode is shown, end of the episode:





Points to remember

- this trace shows an example of inappropriate therapies for supraventricular tachycardia; the ventricular rate is not higher than the atrial rate (V>A rate: false); initially, discrimination is correct with ventricular cycles correlated with the reference ventricular electrogram (RID+); in a second phase, a series of inappropriate therapies is delivered following variable signal quality on the shock channel (RID- and stable rhythm)
- in this example, signal quality was impaired by the oversensing of myopotentials on the shock channel.



The shock channel is recorded between the RV coil and the defibrillator can located in the left pre-pectoral space; it is therefore a "unipolar" signal (only one electrode is located in the heart); this trace shows the poor quality on the shock channel signal due to oversensing of pectoral myopotentials which explains the lack of correlation with the reference ventriculogram and the occurrence of inappropriate therapies.

13 Dual-chamber discrimination and discrimination error due to inappropriate programming of the correlation percentage

Patient

- 79-year-old male with ischemic cardiomyopathy implanted with a Resonate triple-chamber defibrillator

Summary 1

- tachycardia episode with atrial rate equal to the ventricular frequency (V>A: False)
- initially, Rhythm ID correlation: True; inhibition of therapies
- in a second step, Rhythm ID: False; AF: true + stable rhythm (threshold value programmed at 20 ms)
- a burst of ATP is delivered

Trace 1 EGM

1. onset of regular 1/1 tachycardia; first rapid cycle originates in the atrium
2. after 8 consecutive VT or VF cycles, V-Epsd marker; ventricular complexes are correlated
3. end of duration; for the device, the rhythm is stable with a diagnosis of AF; therapies not delivered because RID+ (at least 3 correlated ventricular complexes out of 10).
4. cycle-by-cycle discrimination continues, still with RID+.
5. RID- (less than 3 correlated cycles out of the last 10); stable rhythm with diagnosis of AF: suspicion of dual tachycardia and a burst of ATP is delivered
6. arrhythmia termination

V-123: 14 Jul 2020 14:50, VT, A Rate: 221 min^{-1}, V Rate: 218 min^{-1}

Detail

VT Event Onset

Avg A Rate	221 min^{-1}
Avg V Rate	218 min^{-1}
Detection	Rhythm ID
Template	10 Jul 2020 05:20
RhythmMatch™ Threshold	94 %

At Inhibit

Stability	5 ms
V>A Rate	False
AFib	False
RhythmID Correlated	True
RhythmMatch™	95 %

At V-Detect

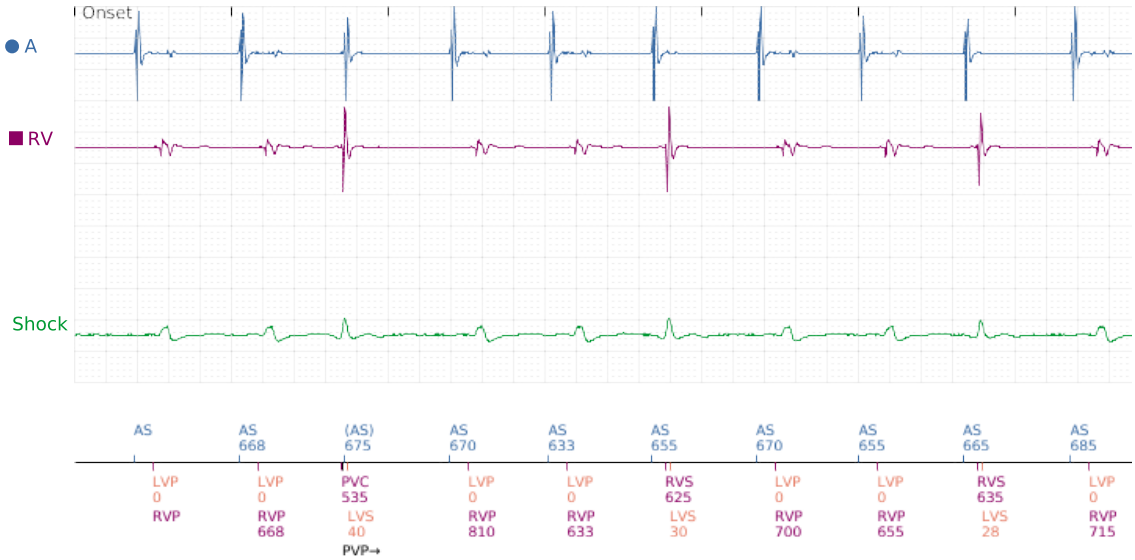
Avg A Rate	184 min^{-1}
Avg V Rate	185 min^{-1}
Rate Zone	VT
RhythmMatch™	93 %
SRD Met	False
ATP Timeout	False

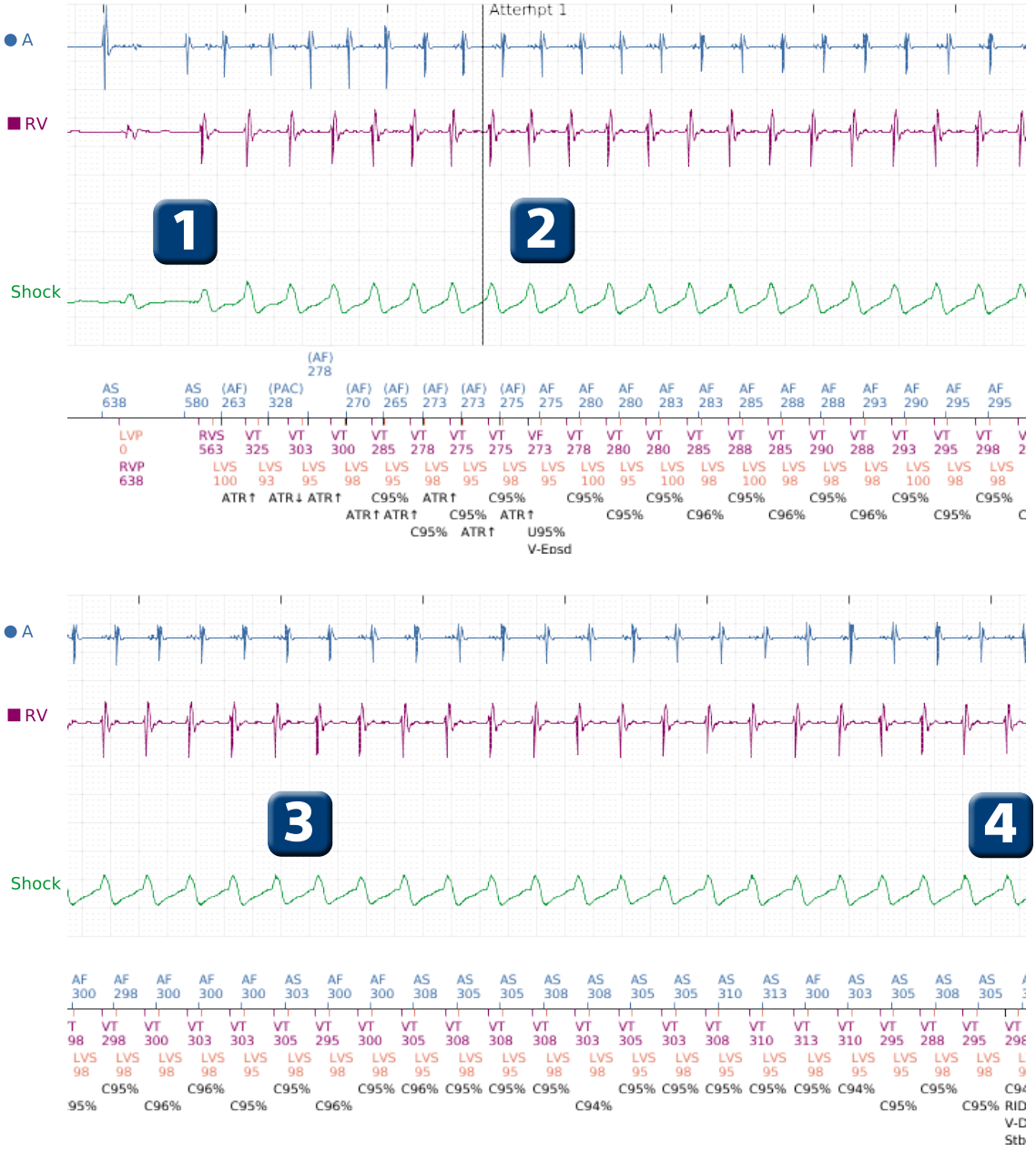
Attempt 1, Burst V ATP

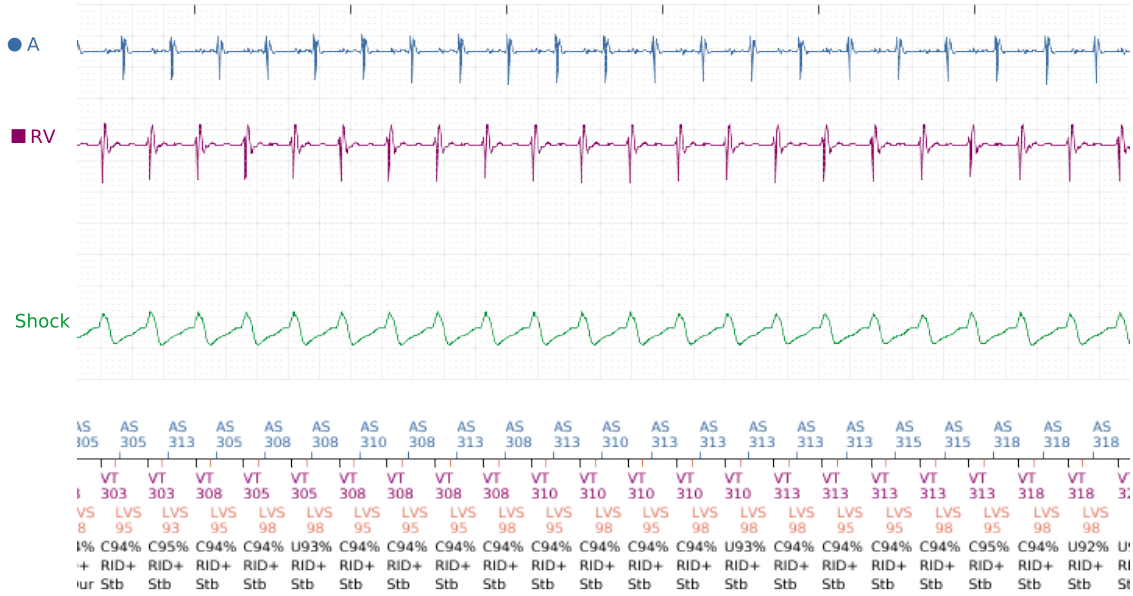
Elapsed Time	00:00:19
Inhibited Attempt	
ATP Information	
Number of Bursts	1

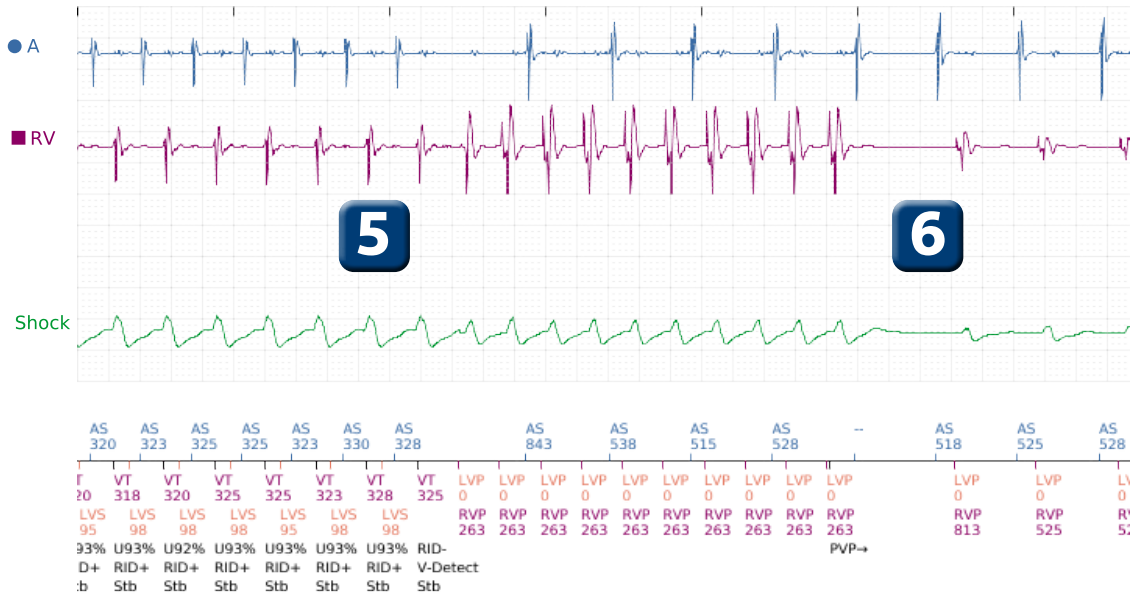
Event Ended 00:00:33

EGM displayed at 25mm per second




Attempt 1
A
RV
Shock
1
2
3
4


A
RV
Shock

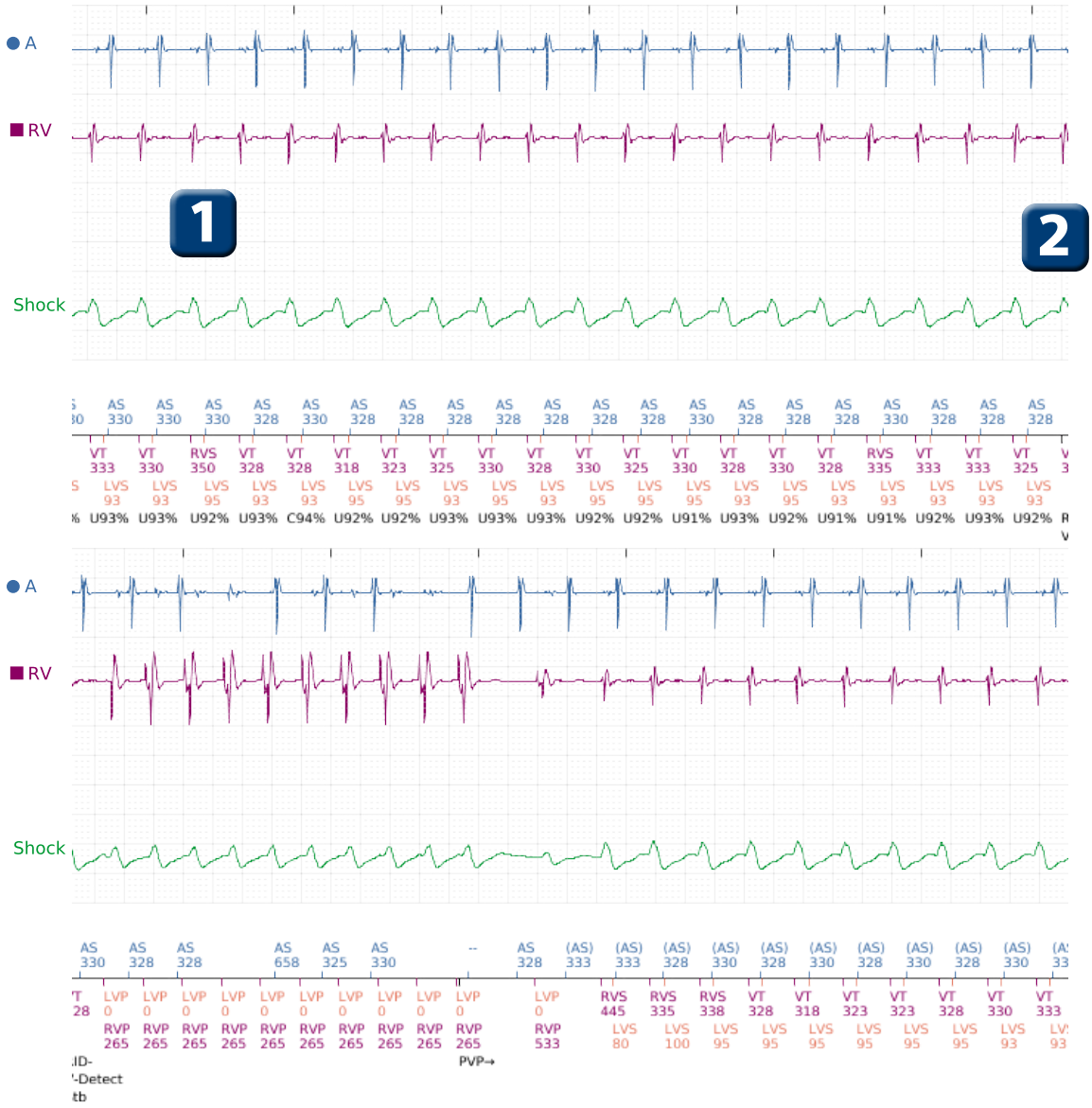

A
RV
5
6
Shock

Summary 2

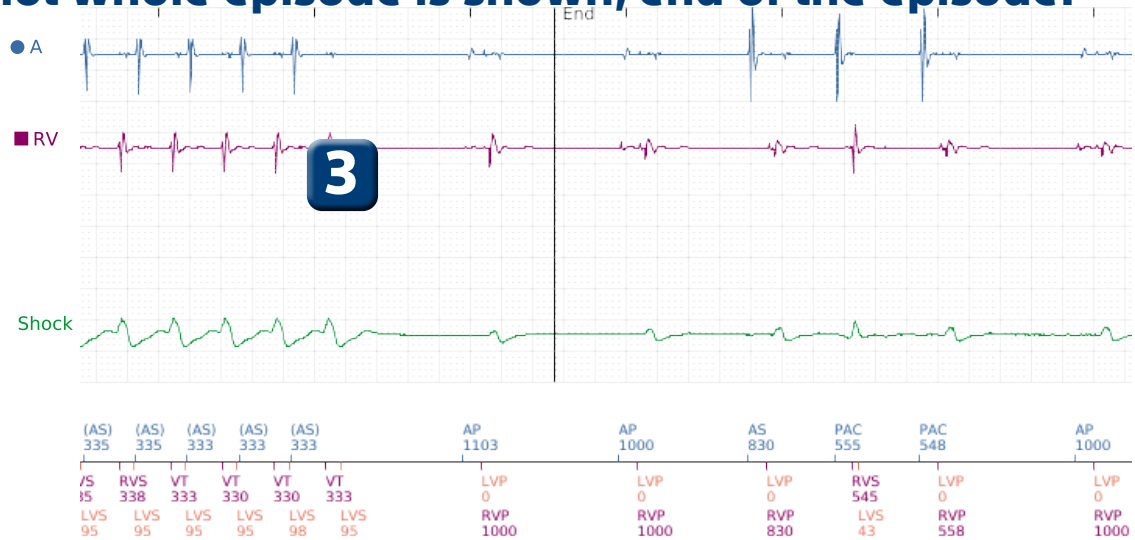
- tachycardia episode with atrial rate equal to ventricular rate (V>A False)
- Rhythm ID: False; AF: false; stable rhythm (threshold value set at 20 ms)
- several bursts and ramps are delivered

Trace 2 EGM

1. regular tachycardia 1/1 same as above
2. end of duration; RID- (less than 3 correlated cycles out of the last 10); stable rhythm and ATP burst
3. spontaneous cessation of tachycardia in the ventricle

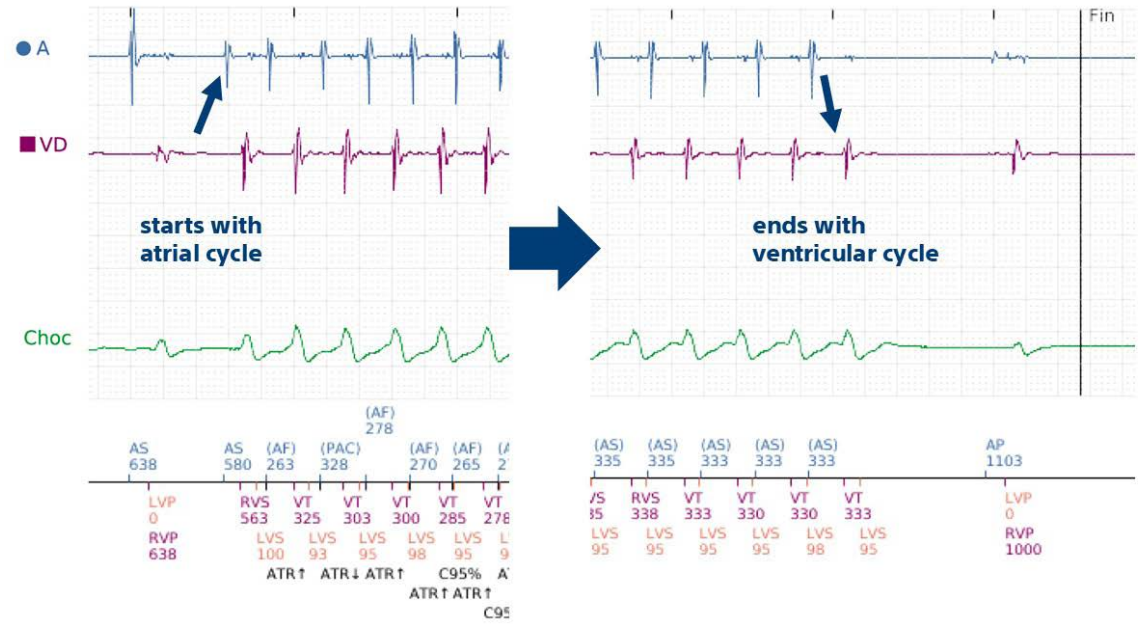


not whole episode is shown, end of the episode:



Points to remember

- this patient presented with episodes of atrial tachycardia that were poorly discriminated as a result of a correlation threshold that was programmed too high; programming a threshold at 88% would have prevented the occurrence of inappropriate therapies
- in the presence of a 1/1 tachycardia, several different diagnoses are possible (VT with retrograde conduction, sinus tachycardia, 1/1 atrial tachycardia, junctional tachycardia); in this patient, certain elements favor the diagnosis of atrial tachycardia: very fast heart rate argument in this 79-year-old patient (not typical for sinus tachycardia), tachycardia starts on a premature atrial cycle (first tracing), tachycardia stops spontaneously on a ventricular event (second tracing); on the first tracing, the tachycardia stops following a burst of ventricular anti-tachycardia pacing, which is not inconsistent with the diagnosis of atrial tachycardia, as a significant number of 1/1 atrial tachycardias can be terminated by ventricular pacing (retrograde conduction and arrhythmia terminated)



This figure illustrates 2 elements in favor of SVT (start of the episode on a premature atrial cycle, end of the episode on a ventricular complex).

14 Dual-chamber discrimination, atrial tachycardia

Patient

- 76-year-old man; ischemic cardiomyopathy with wide QRS; implanted with a triple-chamber defibrillator

Summary

- episode diagnosed in VT zone with atrial rate = ventricular rate
- programmed discrimination: Onset/stability

EGM layout

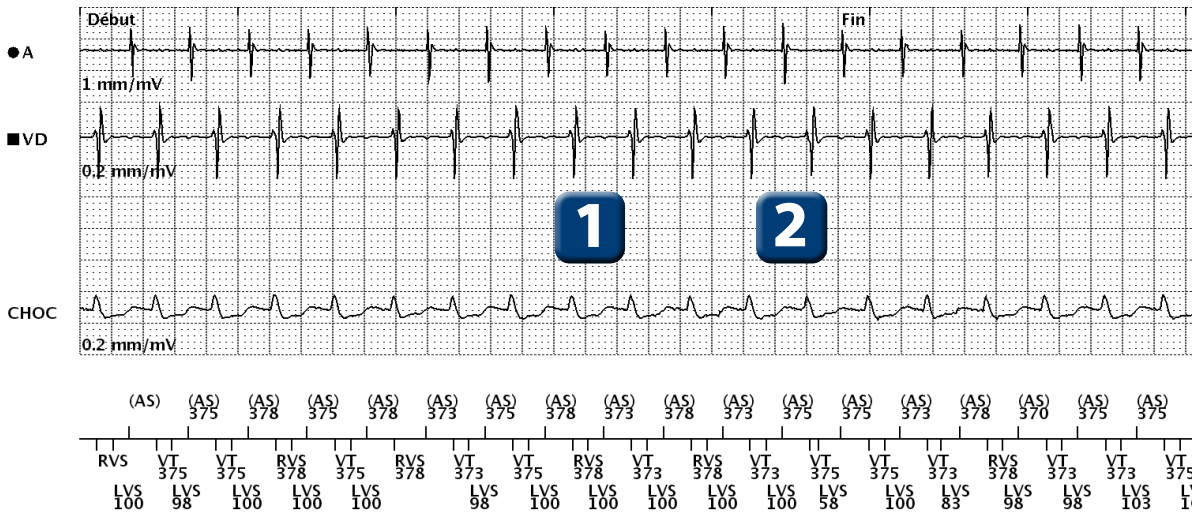
1 rapid ventricular rate with A/V ratio 1/1, on the edge of the VT zone (RVS marker)

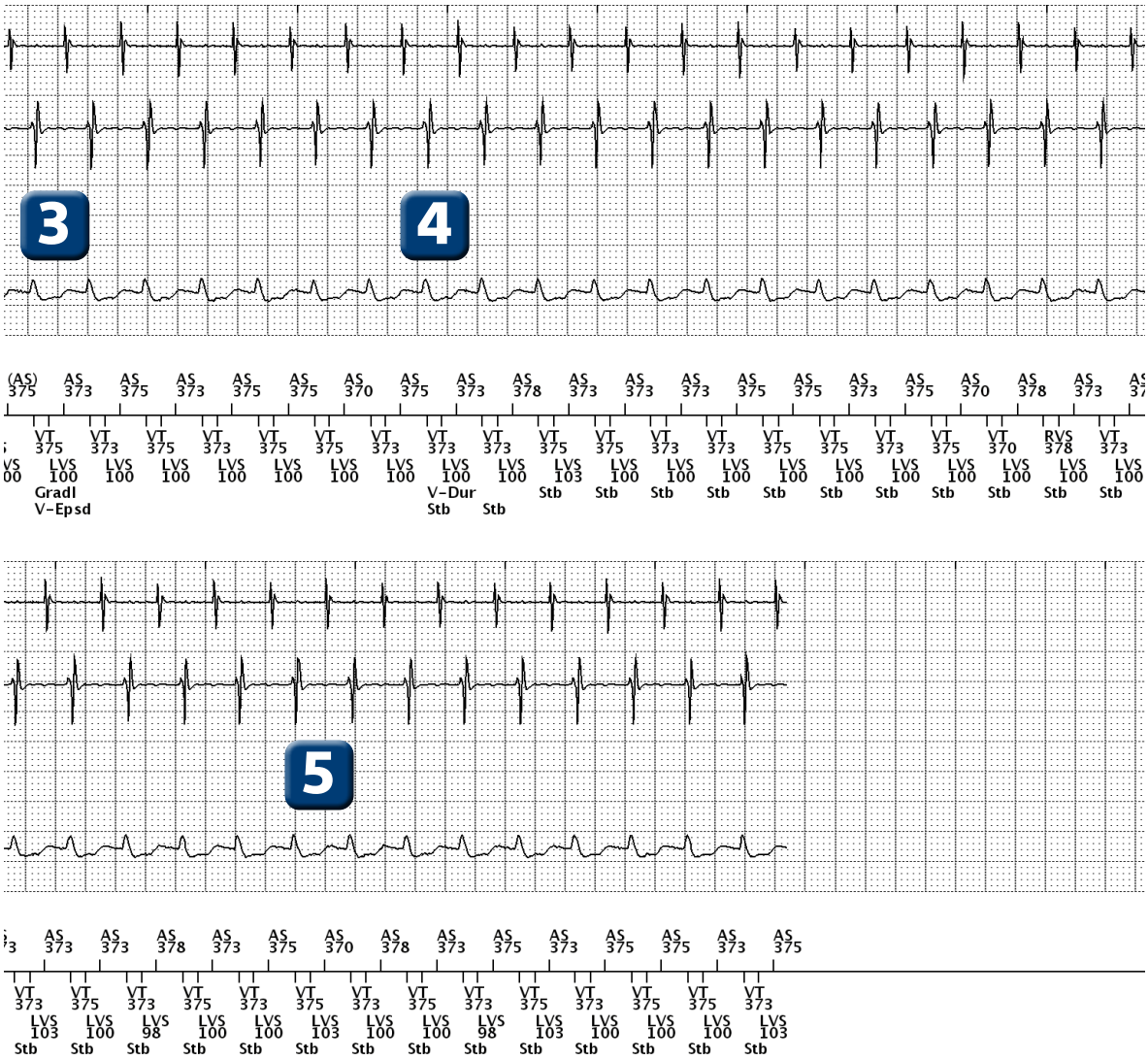
2 slight acceleration of the rhythm into the VT zone (VT zone limit: 375 ms)

3 criterion 8/10 met; analysis of onset of arrhythmia favors sinus tachycardia (Gradl: gradual onset)

4 at the end of the duration, the rhythm is considered stable; no therapy delivered in the presence of a stable rhythm with gradual onset

5 cycle-by-cycle analysis of stability continues; the rhythm is still considered stable and therapies are inhibited





Points to remember

- this episode is diagnosed as sinus tachycardia in the presence of a stable rhythm with gradual onset; therapies are therefore inhibited
- the purpose of the Onset parameter is to inhibit ventricular therapies for the lowest tachycardia zone when the heart rate increase is gradual; its application is limited to the lowest rate zone of a multi-zone configuration; when a detection window is satisfied, the device starts Sudden Onset calculations in two steps; step 1 measures the ventricular intervals preceding the start of the episode and locates the pair of adjacent intervals (pivot point) where the cycle length has decreased the most; if the decrease in cycle

length is equal to or greater than the programmed Onset value, step 1 declares the onset to be sudden; step 2 then compares other intervals; if the difference between the average interval preceding the pivot point and 3 of the first 4 intervals following the pivot point is equal to or greater than the programmed Onset threshold, step 2 declares the onset to be sudden.

- the Onset parameter can be programmed as a percentage of cycle duration or as an interval duration (in ms); the programmed Onset value represents the minimum difference that must exist between intervals above and below the lowest programmed rate threshold.
- this episode corresponds to an episode of sustained atrial tachycardia with 1/1 AV conduction; the tachycardia frequency oscillates around the lower limit of the VT zone, which explains why the onset is considered gradual; in fact, the ventricular rate varies very little but oscillates between the sinus and VT zones; this patient's rhythm initially went from its resting rate (60 beats/minute) to a rate of 165 beats/minute; gradually, the tachycardia rate then accelerated to reach the VT zone; there was therefore a sudden onset that was not diagnosed by the device; paradoxically, the fact that the sudden onset parameter was implemented avoided the patient having to receive inappropriate therapies
- 1/1 atrial tachycardia is not correctly discriminated by the combination of V>A (atrial rate is equal to ventricular rate in 1/1 atrial tachycardia as in VT with 1/1 retrograde conduction), abrupt onset (onset is usually abrupt in atrial tachycardia as in VT) and stability (ventricular rate is usually stable in atrial tachycardia as in VT).
- in this patient, it is advisable to raise the lower limit of the VT zone to avoid overlap between the diagnostic zone and the zones of his clinical atrial tachycardia; similarly, it may be advantageous to use discrimination based on the Rhythm ID

15 Dual-chamber discrimination and atrial fibrillation

Patient

- 76-year-old male implanted with Autogen triple-chamber defibrillator for ischemic cardiomyopathy

Summary

- episode diagnosed in the VT zone with atrial rate greater than ventricular rate
- programmed discrimination: Onset/stability
- initially, inhibition of therapies due to unstable rhythm with diagnosis of AF
- secondly, therapies delivered (bursts, ramps, then 1 maximum output shock)

EGM layout

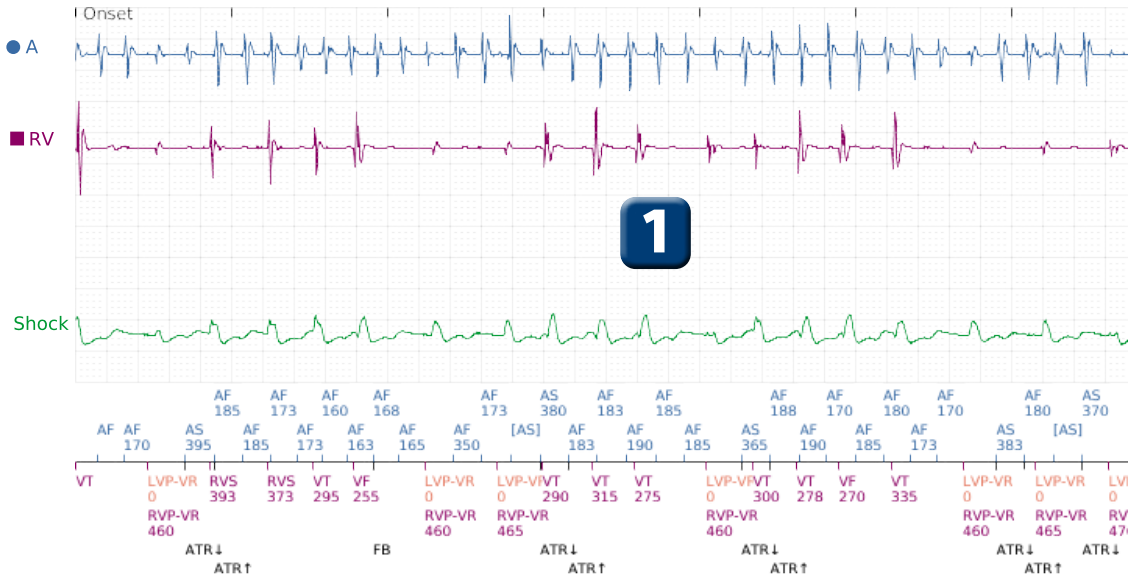
1. AF with irregular conduction
2. V-epsd marker (Gradl: gradual onset)
3. end of duration; inhibition of therapies because of diagnosis of AF with unstable ventricular rhythm
4. rhythm considered stable; first burst of ATP
5. shock terminates atrial arrhythmia

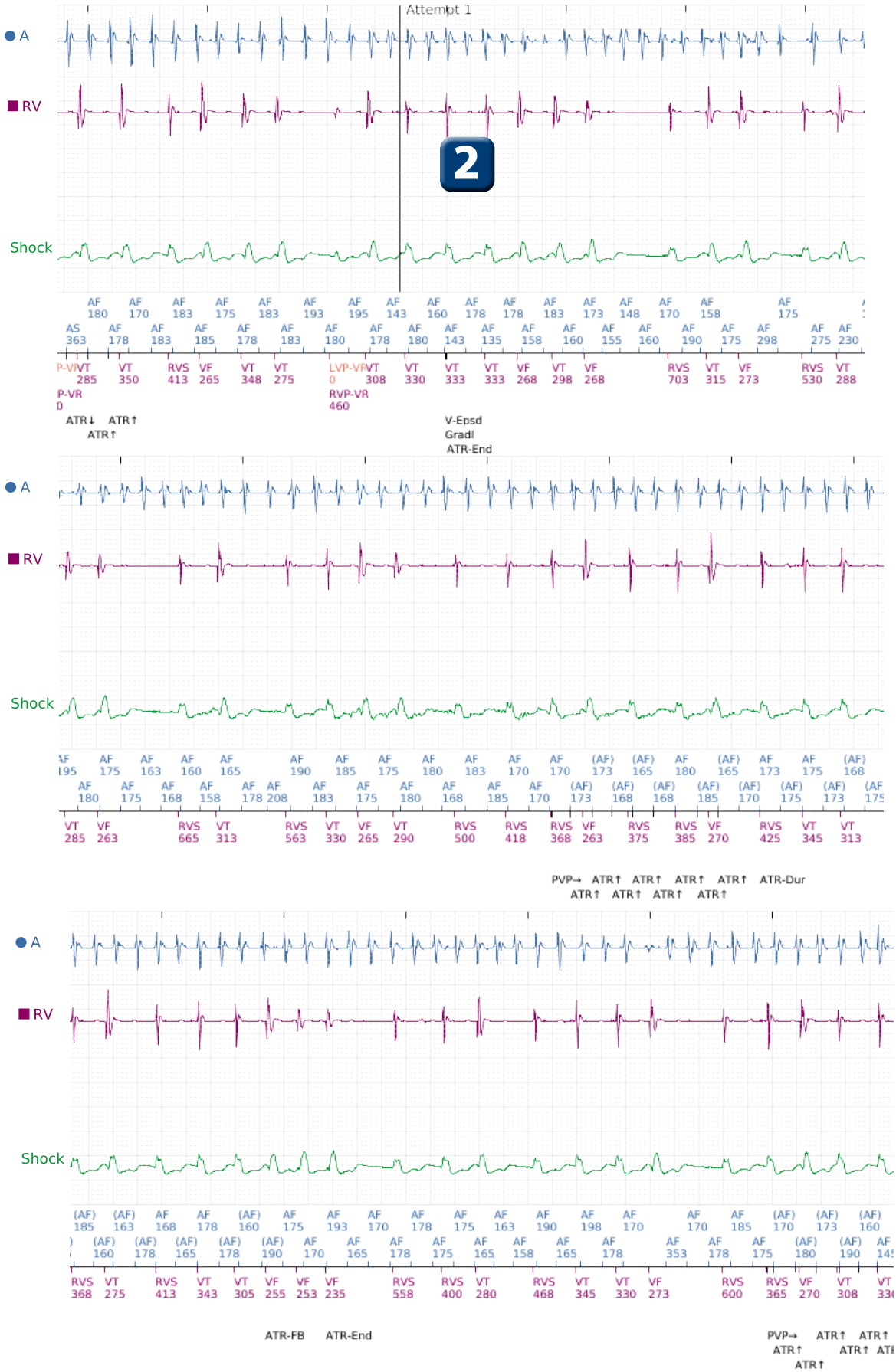
V-3040: 22 May 2022 11:32, VT, A Rate: 385 min^{-1}, V Rate: 168 min^{-1}

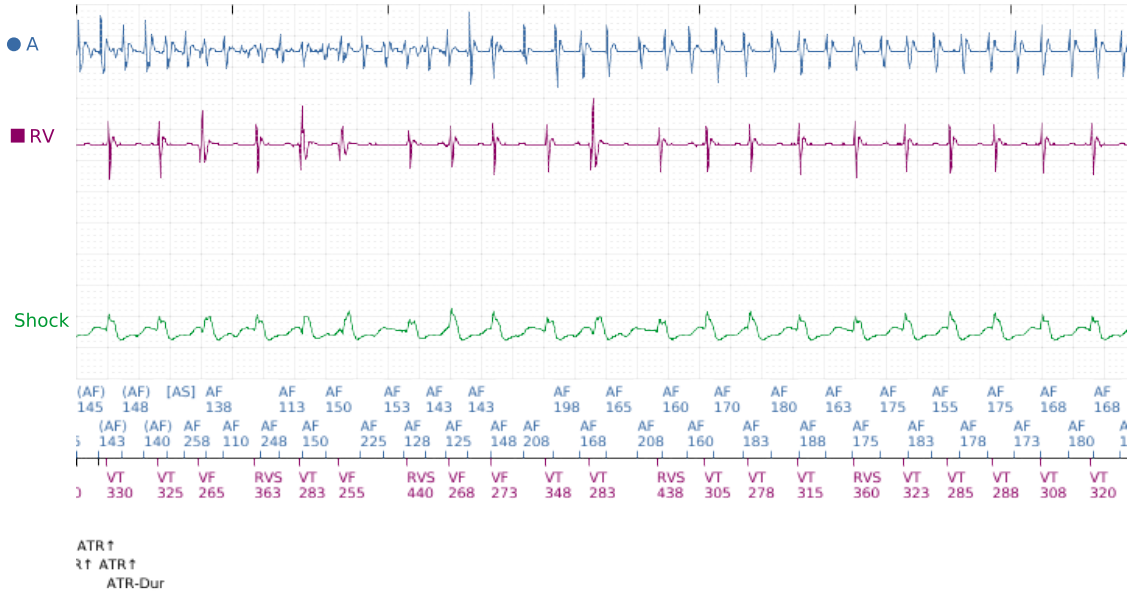
Detail

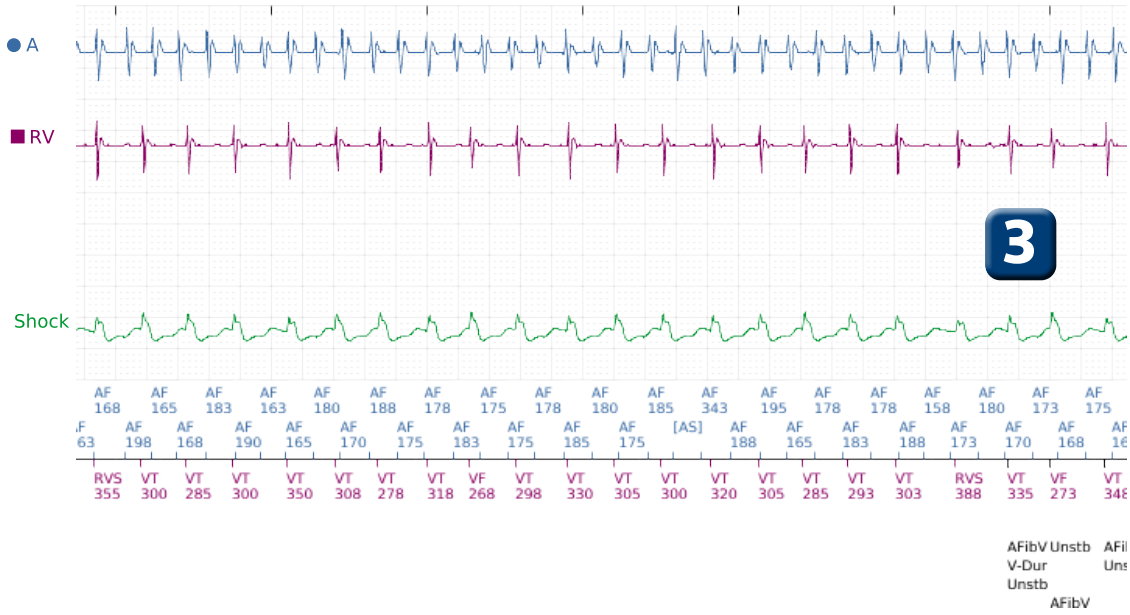
VT Event Onset	
Avg A Rate	385 min^{-1}
Avg V Rate	168 min^{-1}
Detection	Onset/Stability
Onset	Percent
Template	N/R
At Inhibit	
Stability	34 ms
V>A Rate	False
AFib	True
RhythmMatch™	N/R
At V-Detect	
Avg A Rate	368 min^{-1}
Avg V Rate	180 min^{-1}
Rate Zone	VT
RhythmMatch™	N/R
SRD Met	(False, Off)
ATP Timeout	False
Onset Intvl	(0 ms, Off)
Onset %	0 %
At V-Detect	
Avg A Rate	357 min^{-1}
Avg V Rate	159 min^{-1}
Rate Zone	VT
ATP Timeout	False
At V-Detect	
Avg A Rate	296 min^{-1}
Avg V Rate	187 min^{-1}
Rate Zone	VT
ATP Timeout	False

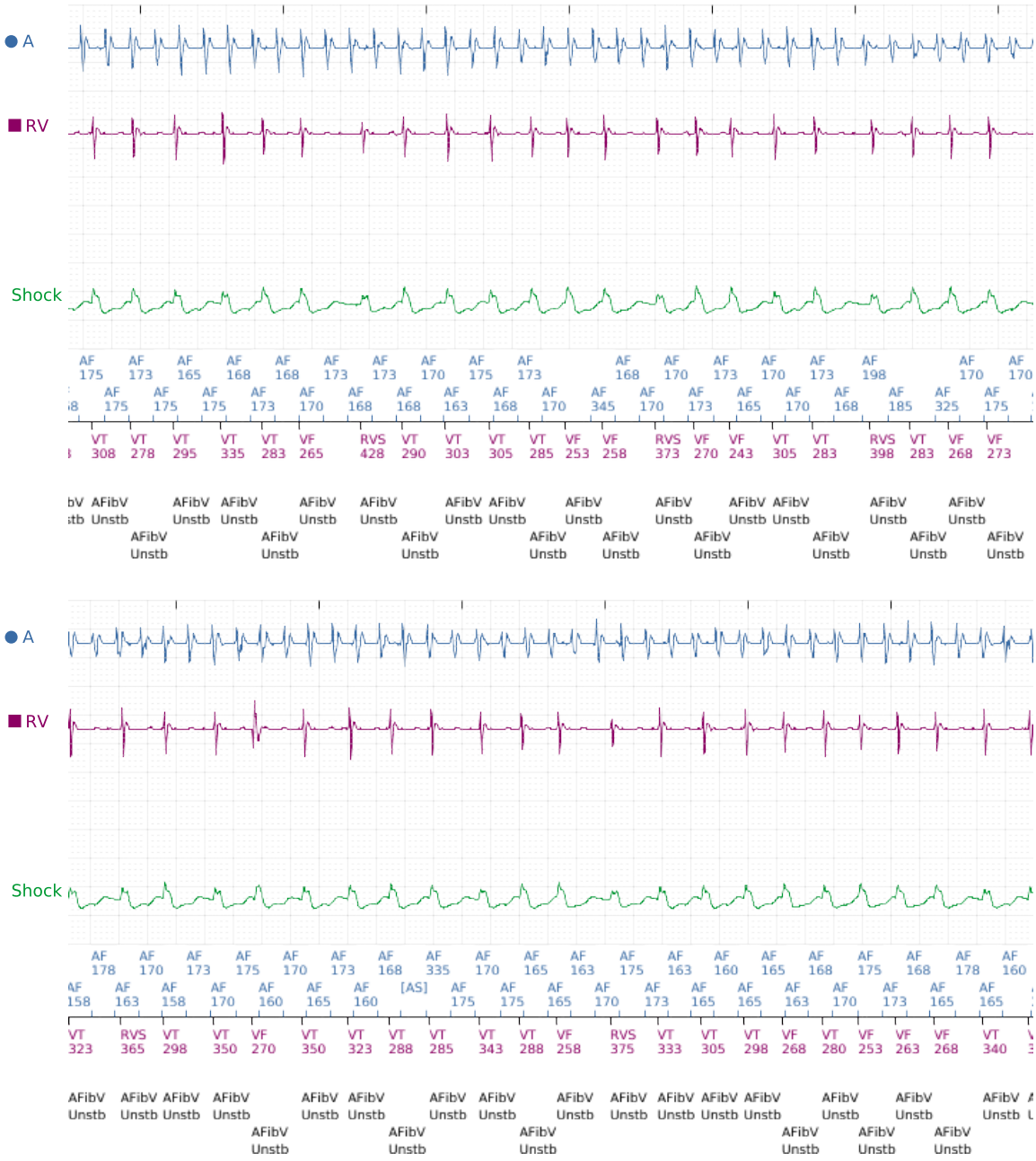
Attempt 1, Burst V ATP	
Elapsed Time	00:00:47
Inhibited Attempt	
ATP Information	
Number of Bursts	3
Attempt 2, Ramp V ATP	
Elapsed Time	00:01:17
ATP Information	
Number of Bursts	3
Attempt 3, 41 J V Shock	
Elapsed Time	00:01:46
Shock Information	
Charge Time	11.9 s
Lead Impedance	57 Ω
Lead Polarity	Initial
Event Ended	00:02:30

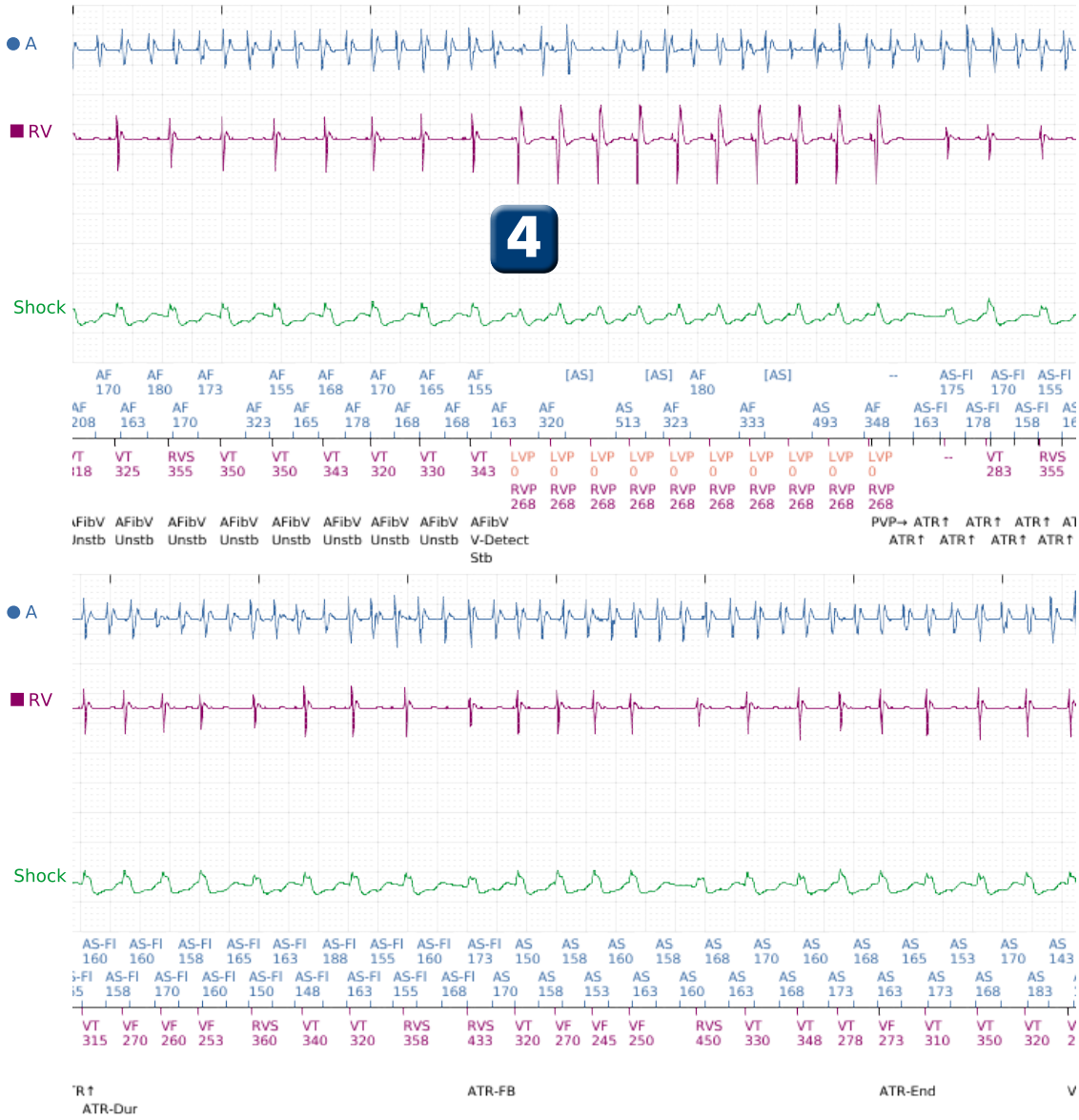



Attempt 1
A
RV
2
Shock
V-Epsd
Gradl
ATR-End
PVP→ ATR↑ ATR↑ ATR↑ ATR↑ ATR-Dur
ATR↑ ATR↑ ATR↑ ATR↑
ATR-FB ATR-End
PVP→ ATR↑ ATR↑
ATR↑ ATR↑

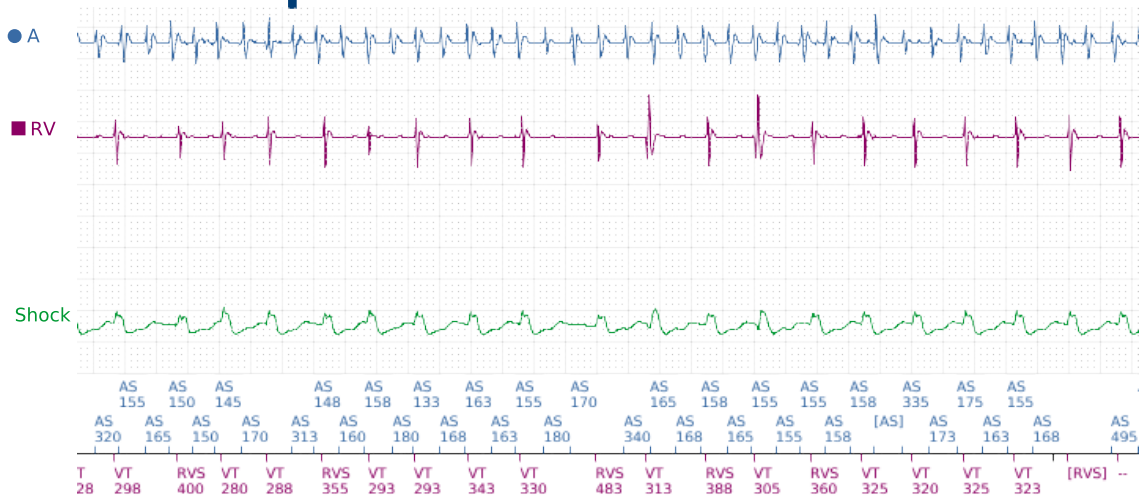

A
RV
Shock
(AF) (AF) [AS] AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF
145 148 138 113 150 153 143 143 198 165 160 170 180 163 175 155 175 168 168
(AF) (AF) AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF
143 140 258 110 248 150 225 128 125 148 208 168 208 160 183 188 175 183 178 173 180
VT VT VF RVS VT VF RVS VF VF VT VT RVS VT VT VT RVS VT VT VT VT VT
330 325 265 363 283 255 440 268 273 348 283 438 305 278 315 360 323 285 288 308 320
ATR↑
ATR↑
ATR-Dur

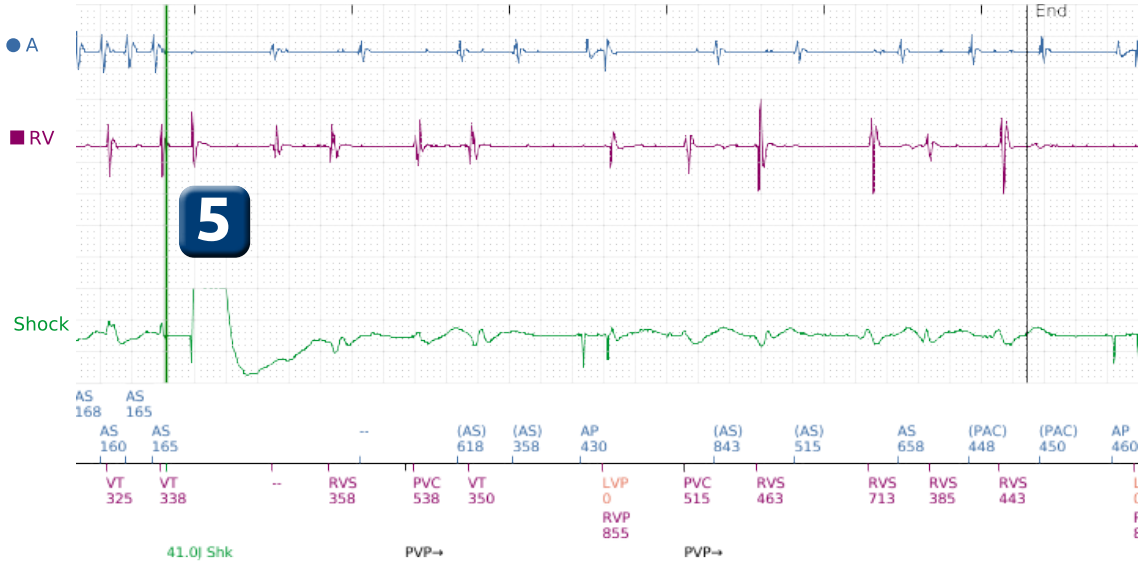

A
RV
Shock
3
AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF AF
168 165 183 163 180 188 178 175 178 180 185 343 195 178 178 158 180 173 175
AF AF AF AF AF AF AF AF AF AF AF [AS] AF AF AF AF AF AF AF AF
198 168 190 165 170 175 183 175 185 175 188 165 183 188 173 170 168
RVS VT VT VT VT VT VT VT VF VT VT VT VT VT VT VT VT VT RVS VT VF VT
355 300 285 300 350 308 278 318 268 298 330 305 300 320 305 285 293 303 388 335 273
AFibV Unstb
V-Dur
Unstb
AFibV


A
RV
Shock
AF 175 AF 173 AF 165 AF 168 AF 168 AF 173 AF 173 AF 170 AF 175 AF 173 AF 168 AF 170 AF 173 AF 170 AF 173 AF 198 AF 170 AF 170
AF 175 AF 175 AF 175 AF 173 AF 170 AF 168 AF 168 AF 163 AF 168 AF 170 AF 345 AF 170 AF 173 AF 165 AF 170 AF 168 AF 185 AF 325 AF 175
VT 308 VT 278 VT 295 VT 335 VT 283 VF 265 RVS 428 VT 290 VT 303 VT 305 VT 285 VF 253 VF 258 RVS 373 VF 270 VF 243 VT 305 VT 283 RVS 398 VT 283 VF 268 VF 273
AFibV Unstb
A
RV
Shock
AF 178 AF 170 AF 173 AF 175 AF 170 AF 173 AF 168 AF 335 AF 170 AF 165 AF 163 AF 175 AF 163 AF 160 AF 165 AF 168 AF 175 AF 168 AF 178 AF 160
AF 158 AF 163 AF 158 AF 170 AF 160 AF 165 AF 160 [AS] AF 175 AF 175 AF 165 AF 170 AF 173 AF 165 AF 165 AF 163 AF 170 AF 173 AF 165 AF 165
VT 323 RVS 365 VT 298 VT 350 VF 270 VT 350 VT 323 VT 288 VT 285 VT 343 VT 288 VF 258 RVS 375 VT 333 VT 305 VT 298 VF 268 VT 280 VF 253 VF 263 VF 268 VT 340
AFibV Unstb



not the whole episode is displayed, end of the episode:



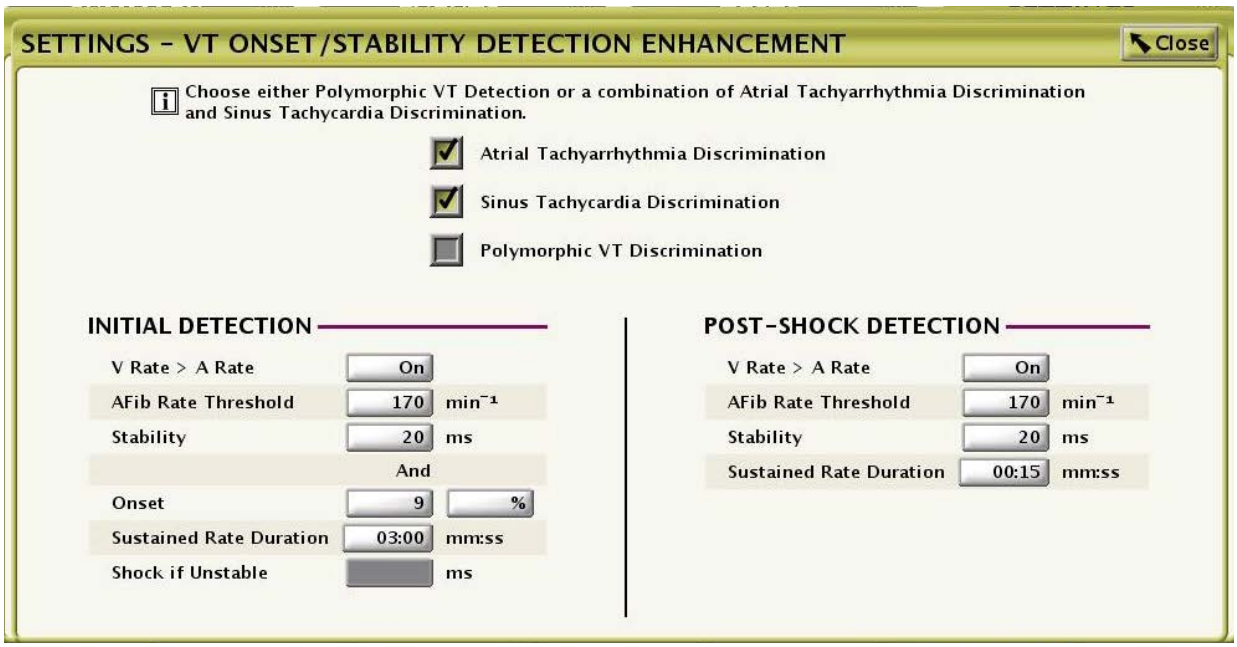


Points to remember

- this episode corresponds to conducted AF, initially well discriminated by the device; the atrial rhythm is rapid, the ventricular rhythm is considered unstable and therapies are inhibited; in a second phase, the ventricular rhythm stabilizes, which is relatively classic for conducted AF with ventricular rates exceeding 160 beats/minute; unsure between conducted AF and dual tachycardia, the device favors sensitivity over specificity and delivers the programmed therapies.
- the stability criterion has been deceived; it was programmed at the nominal value of 20 ms; it is possible to make it less sensitive and more specific (setting discriminators is always a balancing act between sensitivity and specificity) by increasing this value (to 30 or 40 ms, for example)

When discrimination is set to Onset/Stability :

- if the onset is considered sudden and the rhythm is stable, therapies are delivered
- if the onset is considered gradual, the AF criterion is satisfied and the rhythm is stable, the therapies are also delivered
- the setting of the stability parameter and the setting of the rate threshold for AF are decisive:
- when the AF threshold (nominally 170 beats/minute) is set too low (young patient): risk of inappropriate therapies for rapid sinus tachycardia (gradual onset, AF+ criteria, stable rhythm)
- when the stability criterion is programmed too low (20 ms in nominal): risk of inappropriate therapies (as in this example) if conducted AF stabilizes over a few cycles; there is the option of adapting the stability criterion (reprogramming to 30 ms, 40 ms, etc.)



16 dual chamber discrimination, atrial tachycardia

Patient

- 63-year-old male with ischemic cardiomyopathy; implanted with Autogen triple-chamber defibrillator

Summary 1

- episode diagnosed in the VT zone with atrial rate equal to ventricular rate
- programmed discrimination: Onset/stability
- therapy delivered (1 burst), due to the diagnosis of AF and stable rhythm

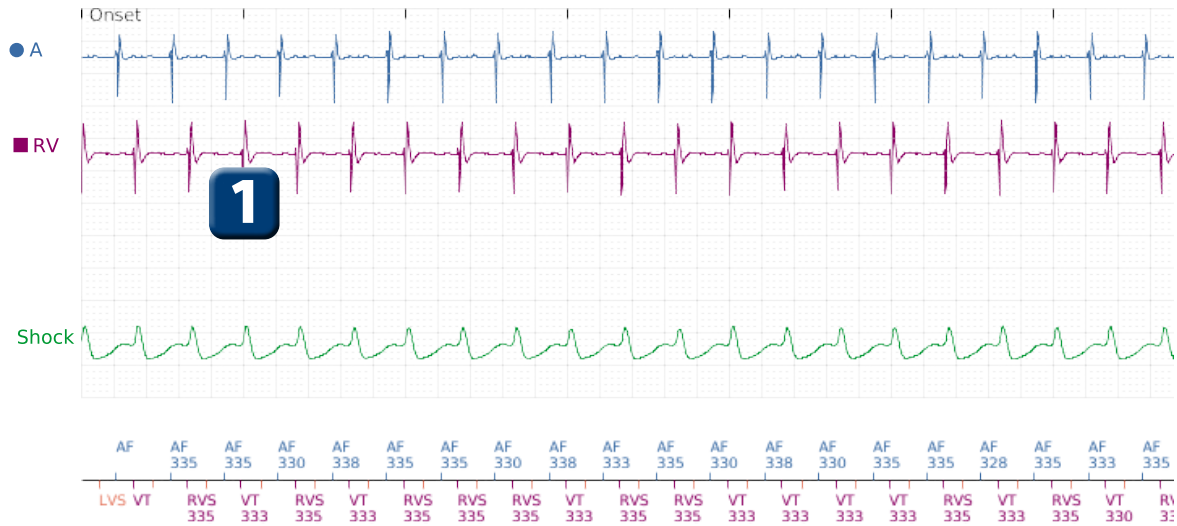
Tracé 1 EGM

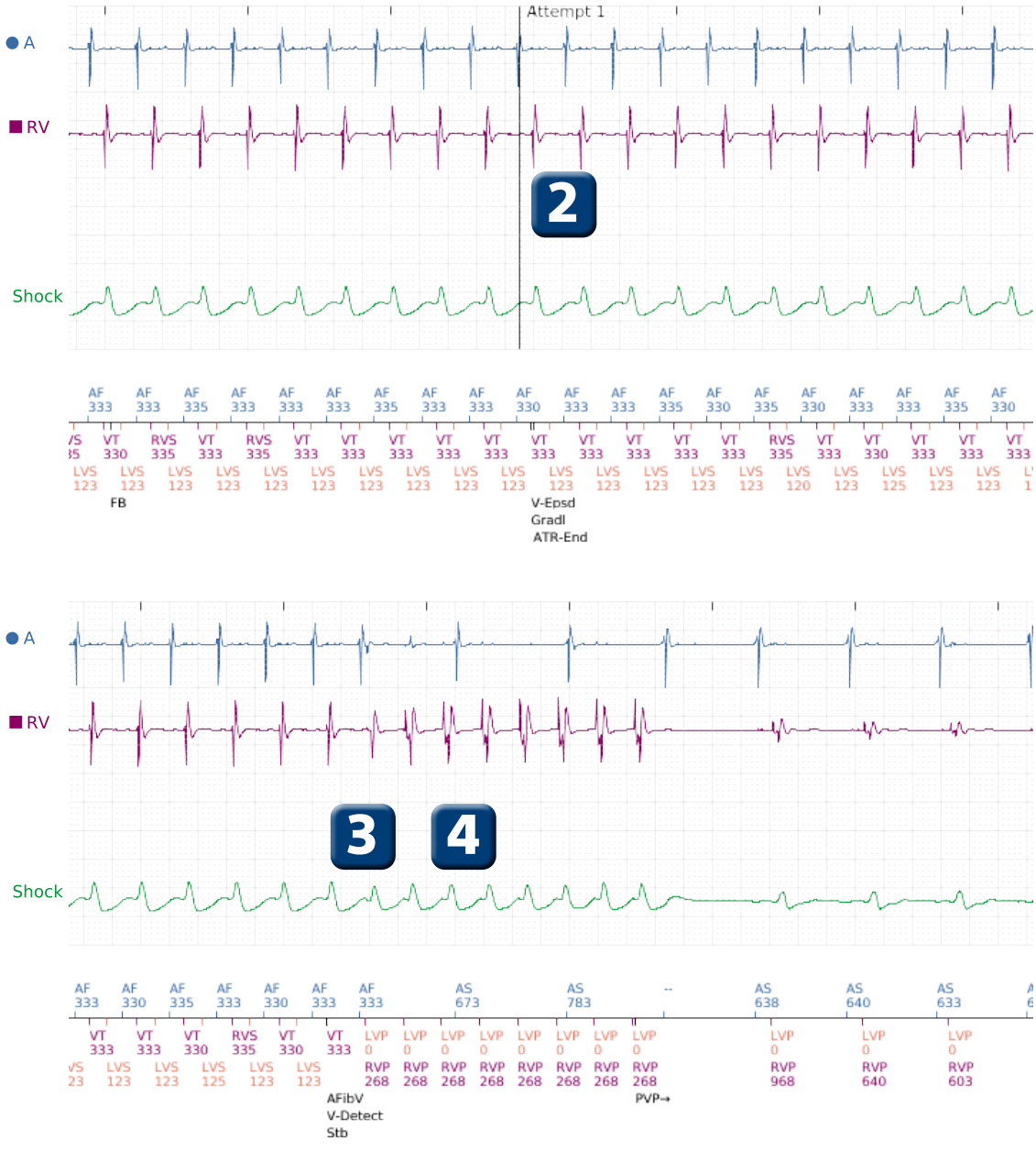
1 regular 1/1 tachycardia with atrial cycles classified as AF

2 V-epsd marker (Gradl: gradual onset)

3 end of duration; diagnosis of AF with stable ventricular rhythm

4 ATP burst restores sinus rhythm





The programming of this patient has been modified with the programming of the Rhythm ID discrimination.

Summary 2

- episode diagnosed in the VT zone with atrial rate equal to ventricular rate
- programmed discrimination: Rhythm ID
- inhibition of therapy (RID+)

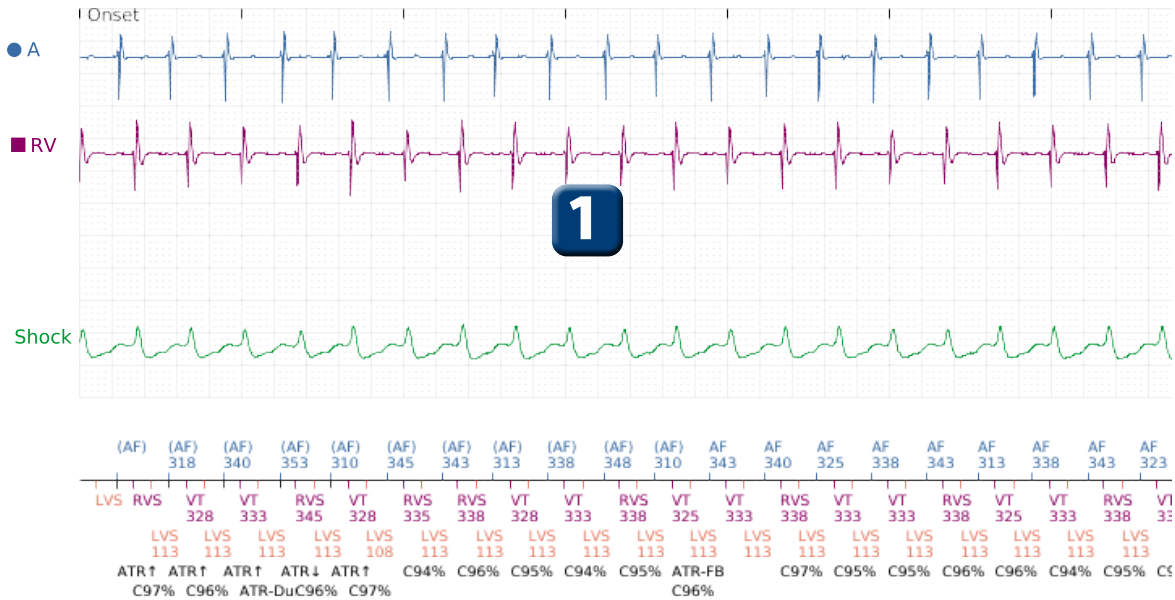
Tracé 2 EGM

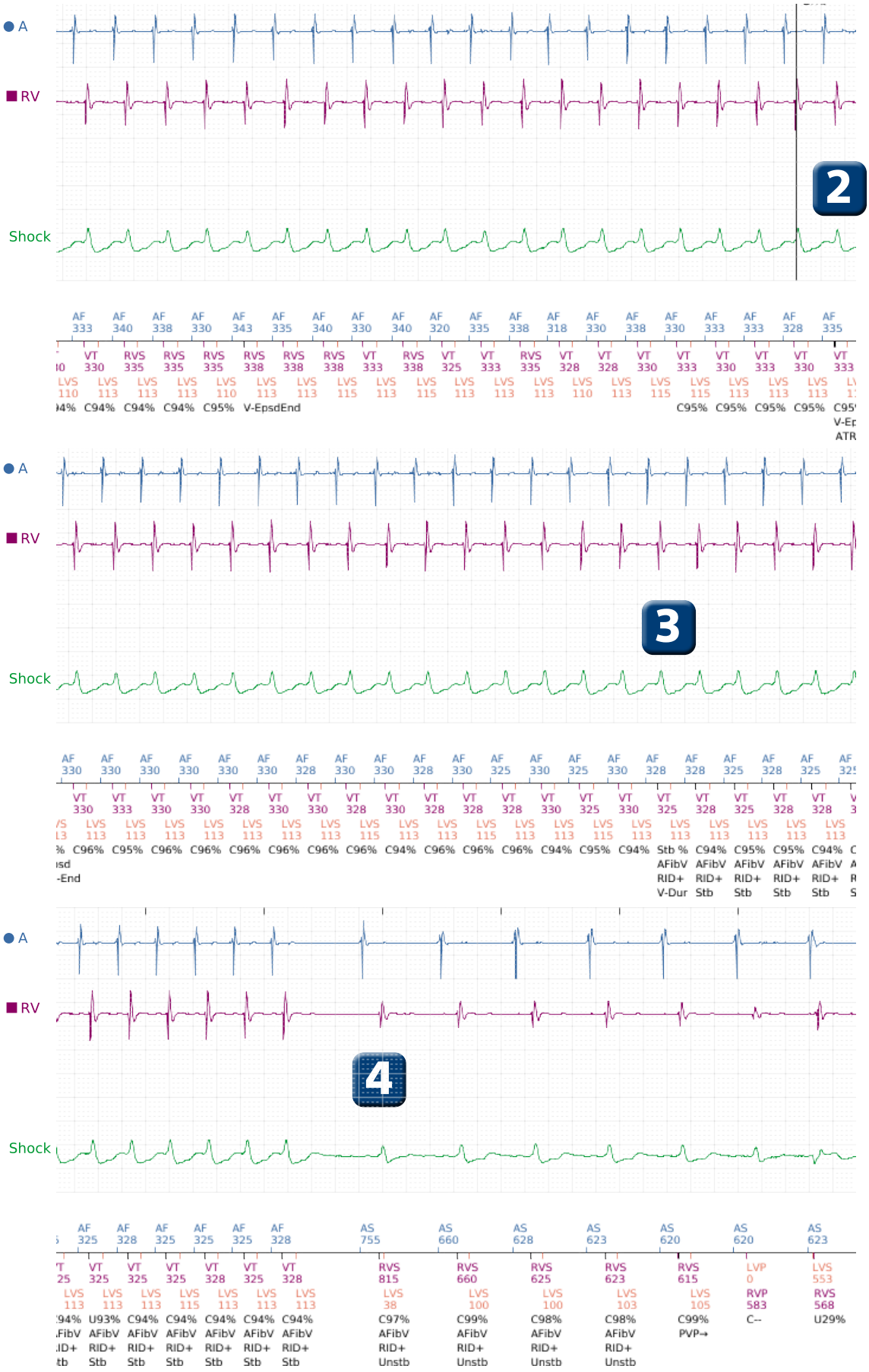
1 regular tachycardia 1/1 same as above

2 V-epsd marker

3 end of duration; inhibition of therapies because RID+.

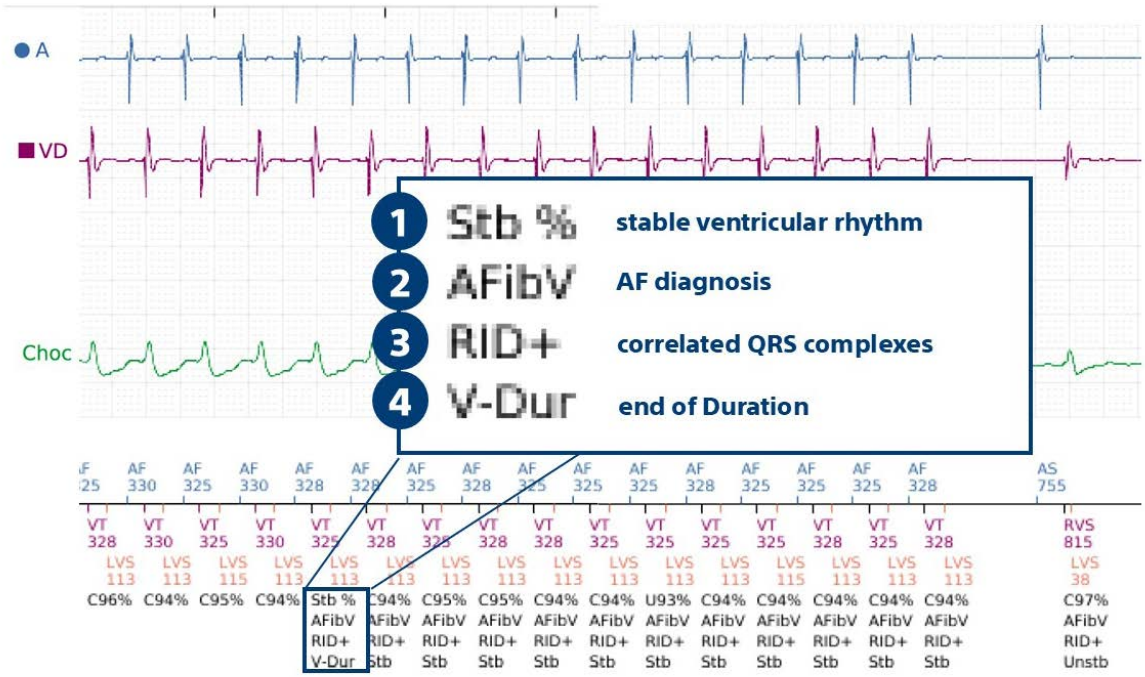
4 spontaneous termination in the ventricle (favors a diagnosis of atrial tachycardia)




A
RV
Shock
2
3
4
AF 333 340 338 330 343 335 340 330 340 320 335 338 318 330 338 330 333 333 328 335
VT 330 335 335 335 338 338 338 333 338 325 333 335 328 328 330 333 333 330 333 330 333
LVS 110 113 113 113 110 113 113 115 113 115 113 113 113 110 113 115 115 113 113 113
C94% C94% C94% C94% C95% V-EpsdEnd
C95% C95% C95% C95%
AF 330 330 330 330 330 330 328 330 330 328 330 325 330 325 330 328 328 325 328 325 328
VT 330 333 330 330 328 330 330 328 330 328 328 328 330 330 325 330 325 328 325 328 328
LVS 113 113 113 113 113 113 113 115 113 115 113 113 113 113 115 113 113 113 113 113 113
C96% C95% C96% C96% C96% C96% C96% C96% C94% C96% C96% C96% C94% C95% C94% Stb % C94% C95% C95% C94%
AFibV AFibV AFibV AFibV AFibV
RID+ RID+ RID+ RID+ RID+
V-Dur Stb Stb Stb Stb
AF 325 328 325 325 325 328
VT 325 325 325 325 328 325 328
LVS 113 113 113 115 113 113 113
U93% C94% C94% C94% C94% C94%
AFibV AFibV AFibV AFibV AFibV AFibV
RID+ RID+ RID+ RID+ RID+ RID+ RID+
Stb Stb Stb Stb Stb Stb Stb
AS 755 660 628 623 620 620 623
RVS 815 660 625 623 615 0 553
LVS 38 100 100 103 105 RVP 583 RVS 568
C97% C99% C98% C98% C99% C-- U29%
AFibV AFibV AFibV AFibV PVP→
RID+ RID+ RID+ RID+
Unstb Unstb Unstb Unstb

Points to remember

- these 2 traces illustrate the complexity of defibrillator programming; in the first trace, 1/1 atrial tachycardia is poorly discriminated by the Onset/Stability algorithm; in fact, the atrial rate exceeds the AF threshold and the rhythm is stable; the device suspects a possible dual tachycardia and delivers a burst of anti-tachycardia pacing which terminates the atrial arrhythmia; it is therefore an inappropriate therapy that has a beneficial effect; this type of 1/1 atrial tachycardia is almost systematically poorly discriminated by this algorithm, therefore a decision was made to switch to the Rhythm ID option, since the morphology criterion is theoretically effective in this type of tachycardia
- the second plot shows that an identical episode of tachycardia (1/1 atrial tachycardia) that is then correctly discriminated in this patient with inhibition of therapies; the episode ends spontaneously, which raises the question of reprogramming the initial duration (lengthening it significantly) in the VT zone so as to maximize the probability of spontaneous termination without intervention of the discrimination algorithm; another option is to increase the lower limit of the VT zone (to 200 beats/minute for example), so as to avoid any overlap between the rates of this atrial tachycardia and the rates of possible VT.



On the second trace:

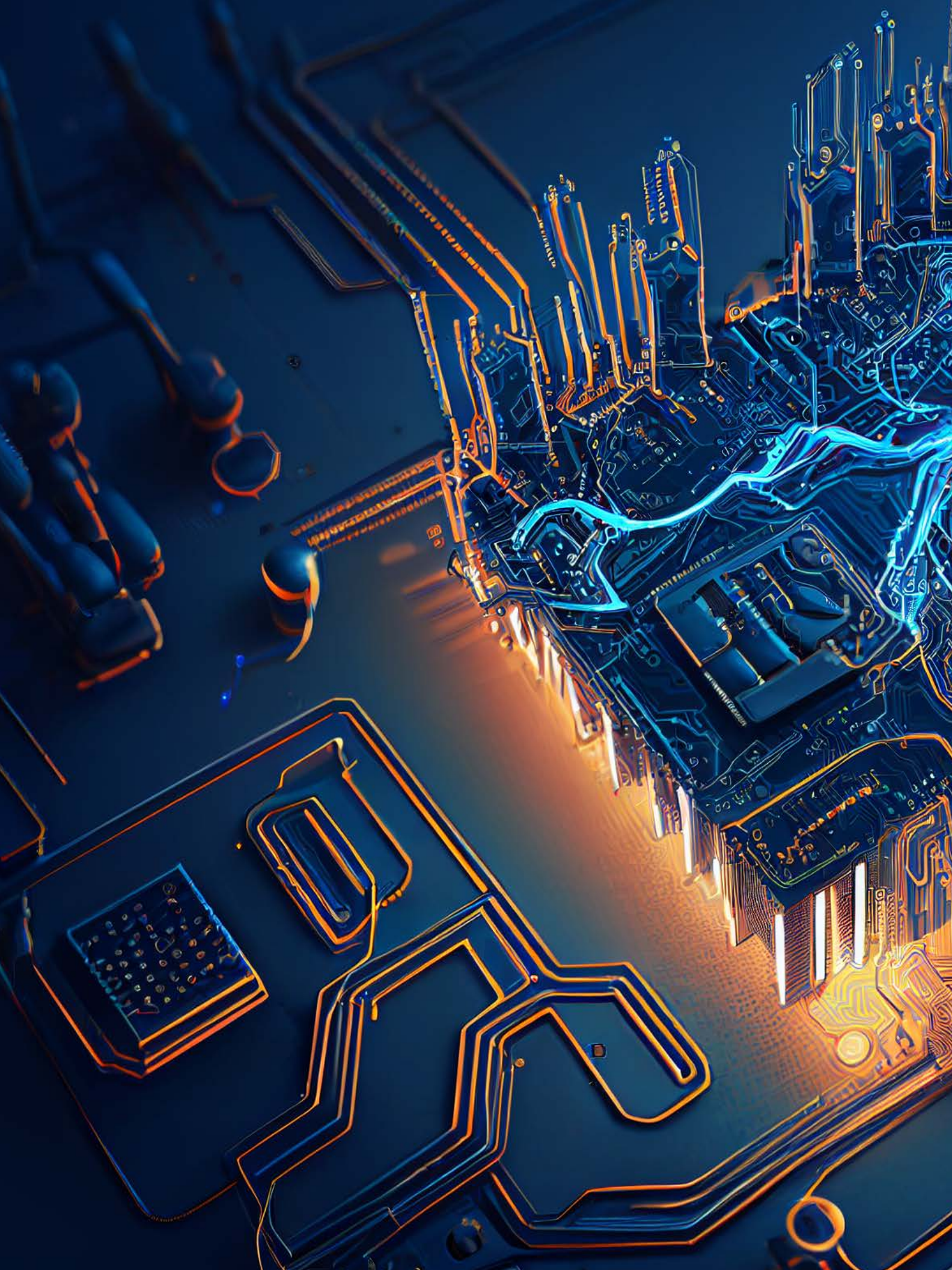
- the rhythm is stable with a diagnosis of AF: this would therefore lead to a diagnosis of VT if the Onset/Stability algorithm had been programmed
- QRS complexes are correlated (RID+), which explains why therapies are inhibited

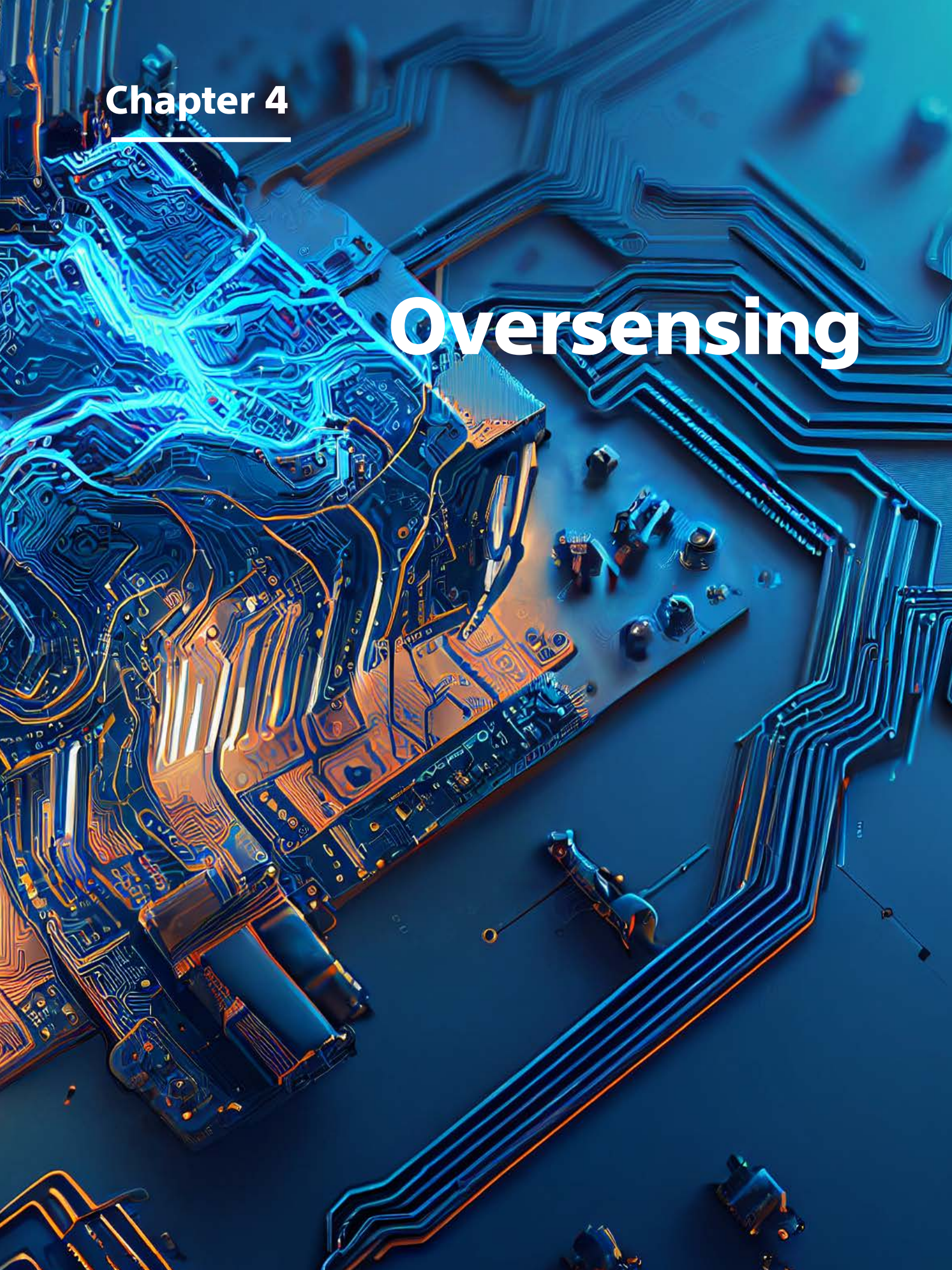
Articles worth reading

- Moss A.J., Schuger C., Beck C.A. Reduction in inappropriate therapy and mortality through ICD programming. N Engl J Med. 2012: ***this article discusses different programming options (increasing the number of cycles in initial detection, programming high low bounds for tachycardia zones, discrimination) to reduce the percentage of inappropriate therapies.***
- Gard J.J., Friedman P.A. Strategies to Reduce ICD Shocks: The Role of Supraventricular Tachycardia-Ventricular Tachycardia Discriminators. Card Electrophysiol Clin. 2011
- Mansour F., Khairy P. Programming ICDs in the Modern Era beyond Out-of-the Box Settings. Pacing Clin Electrophysiol. 2011: ***these 2 articles discuss the advantages***

and disadvantages of different discriminators for reducing the percentage of inappropriate therapies.

- Goncalves J., Pereira T. Inappropriate shocks in patients with ICDs: single chamber versus dual chamber. Arq Bras Cardiol. 2013: ***these 2 meta-analyses find no superiority of dual-chamber versus single-chamber discrimination in terms of mortality or occurrence of inappropriate therapies.***
- Brugada J., Mont L., Figueiredo M., et al. Enhanced detection criteria in implantable defibrillators. J Cardiovasc Electrophysiol. 1998: ***this study shows that programming a 3-minute timer can lead to inappropriate therapy in 10% of cases.***
- Daubert J.P., Zareba W., Cannom D.S. Inappropriate implantable cardioverter-defibrillator shocks in MADIT II: frequency, mechanisms, predictors, and survival impact. J Am Coll Cardiol. 2008: ***this multicenter study shows that 50% of SVTs have a frequency greater than 170 beats/minute, and that some episodes can reach a frequency of 250 beats/minute.***
- Dorian P., Philippon F., Thibault B. Randomized controlled study of detection enhancements versus rate-only detection to prevent inappropriate therapy in a dual-chamber implantable cardioverter-defibrillator. Heart Rhythm. 2004: ***this study shows the respective interest of certain discriminants (V>A...) in reducing the percentage of inappropriate therapies.***
- Glikson M., Swerdlow C.D., Gurevitz O.T. Optimal combination of discriminators for differentiating ventricular from supraventricular tachycardia by dual-chamber defibrillators. J Cardiovasc Electrophysiol. 2005: ***this article discusses the value of combining discriminators to reduce the percentage of inappropriate therapies.***
- Frontera A, Strik M, Eschalier R, et al. Electrogram morphology discriminators in implantable cardioverter defibrillators: A comparative evaluation. J Cardiovasc Electrophysiol. 2020: ***this article analyzes the diagnostic yield of morphology-based discrimination according to manufacturers; the nominal value of 94% on Boston Scientific devices is associated with perfect sensitivity but very low specificity.***





Chapter 4

Oversensing

1 Oversensing of electrocautery

Patient

- male with ischaemic cardiomyopathy, implanted with a triple chamber defibrillator; box change procedure with implantation of a Resonate defibrillator; electrogram trace recorded during the procedure.

Summary

- detection of an episode in the VF zone
- no therapy delivered (device not programmed for monitoring + treatment)

EGM layout

1 atrial sensing and biventricular pacing

2 simultaneous sensing on all 3 channels (atrial, ventricular, shock) of fast, disorganized signals of variable amplitude and morphology (classified as AF, VF)

3 end of oversensing

4 new onset oversensing of identical signals

V-1: 18 Jan 2021 11:33, VF, A Rate: 303 min^{-1}, V Rate: 296 min^{-1}

Detail

VF Event Onset

Avg A Rate	303 min^{-1}
Avg V Rate	296 min^{-1}
Detection	Onset/Stability
Onset	Percent
Template	N/R

At V-Detect

Avg A Rate	303 min^{-1}
Avg V Rate	181 min^{-1}
Rate Zone	VF
Stability	(85 ms, Off)
V>A Rate	(False, Off)
AFib	(True, Off)
RhythmMatch™	N/R
SRD Met	(False, Off)
ATP Timeout	False
Onset Intvl	(577 ms, Off)
Onset %	58 %

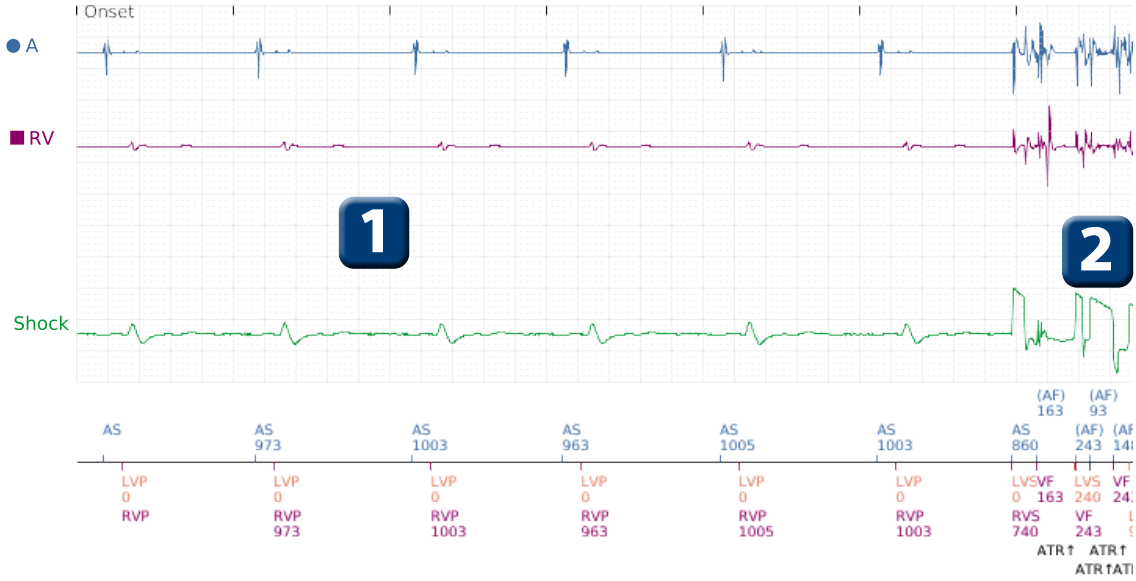
Event Ended 00:00:20

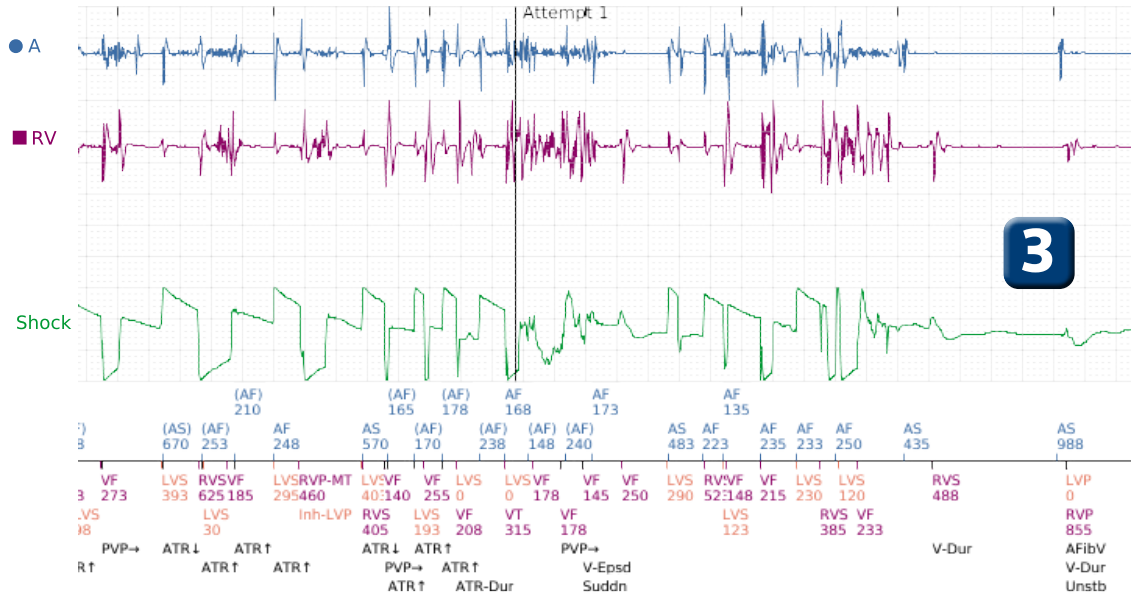
Attempt 1, Non Therapy V

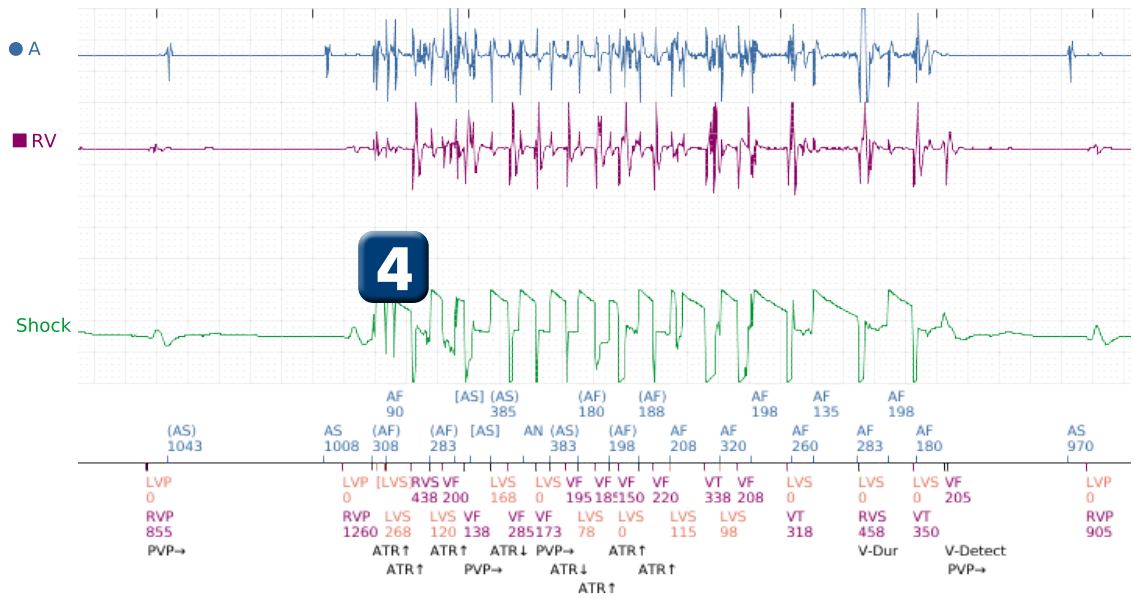
Elapsed Time 00:00:09

Attempt Information

No therapy delivered, Tachy therapy mode is not programmed to Monitor+Therapy.


Onset
A
RV
Shock
1
2

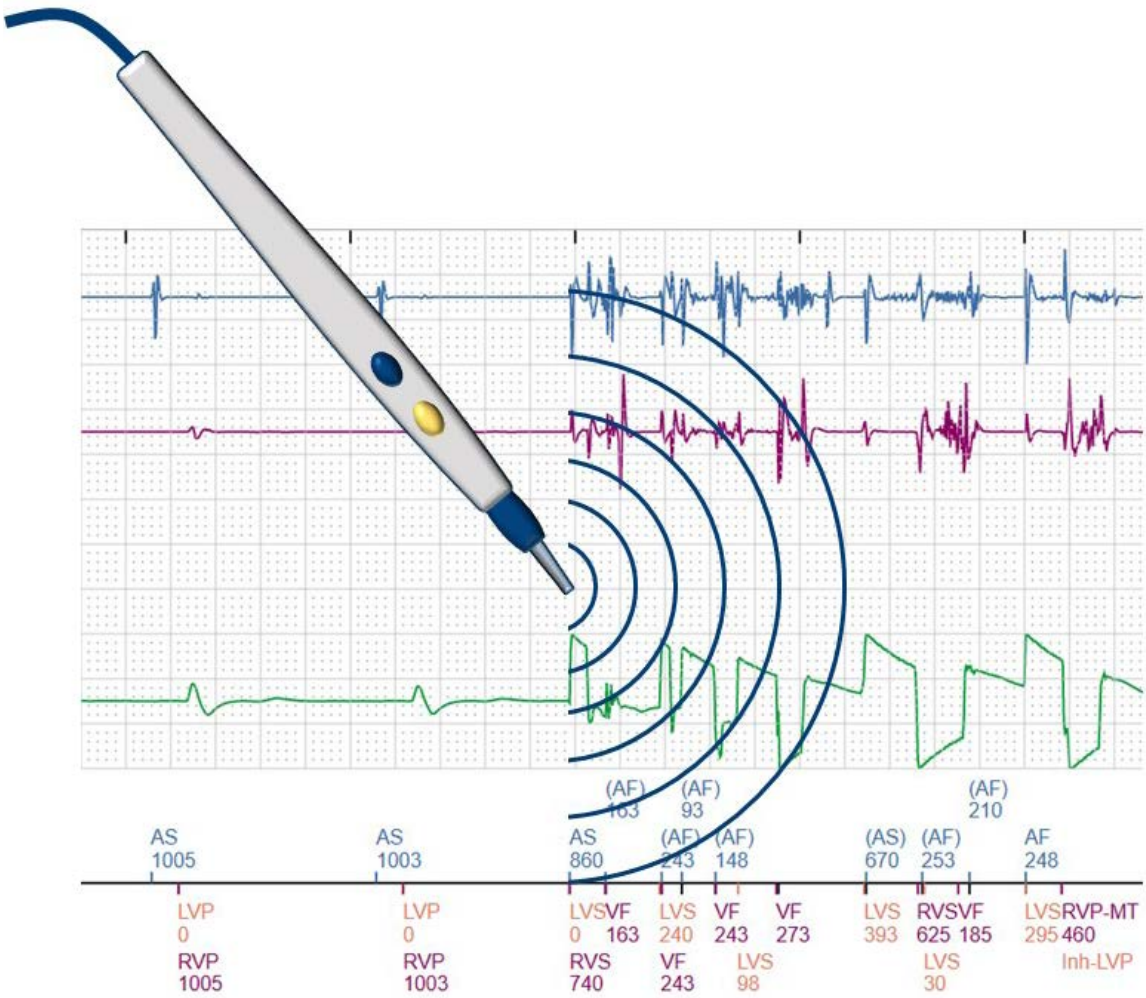

Attempt 1
A
RV
Shock
3


A
RV
Shock
4

Points to remember

- the programmed Tachy Mode controls the availability of detection and treatment functions with 3 programmable options: 1) off: deactivates arrhythmia detection and delivery of therapies; 2) monitoring only: deactivates therapies but allows detection and recording of arrhythmia episodes; 3) monitoring + treatment: activates detection and recording functions as well as the various programmed therapies.
- in this patient, the Tachy Mode was programmed to monitoring only during the device change procedure, which explains the detection and recording of this episode but the absence of therapy delivered; once the device was connected and positioned in the pocket, electrocautery was used for hemostasis
- as a general rule, the diagnosis of electromagnetic interference is based on exposure to a source at the time of the recorded episode and oversensed signals with a characteristic pattern; oversensing of electromagnetic interference is more common with an integrated bipolar lead than with «true» bipolar sensing, as the sensing antenna is larger
- the tracing is characteristic for oversensing of a signal emitted by an electrocautery unit: simultaneous sensing on the 3 channels (atrial, ventricular, shock) of rapid, disorganized signals of variable amplitude and morphology; the diagnosis is obvious insofar as the episode was recorded during the device change procedure
- when changing the device, it is customary to program the Tachy Mode to off to avoid inappropriate therapies and recording tracings which unnecessarily overload the device's memories
- in dependent patients, a specific mode can be programmed for asynchronous pacing (AOO, VOO or DOO) to avoid inhibition during electrocautery
- in a patient implanted with a defibrillator and undergoing non-cardiac surgery, the surgeon should be advised to use electrocautery in bipolar mode, to limit its use to very short periods and to place the scalpel plates at a distance from the defibrillator unit; to completely eliminate the risk of unwanted interference, a first option is to deprogram

detection and therapies; a second option is to place a magnet over the defibrillator to inhibit all therapy; the effect of the magnet is reversible, and the therapies and episode memory are operational again once the magnet is removed; during the procedure, scope monitoring must be maintained, as the patient is no longer protected by his defibrillator



This figure shows the characteristic trace of an oversensing of electrocautery, with disorganized signals appearing simultaneously on the 3 channels.

2 Surgical intervention and VF at the time of reperfusion

Patient 1

- Male with ischaemic cardiomyopathy, implanted with a Momentum triple-chamber defibrillator; aortic valve replacement surgery; trace recorded during the procedure

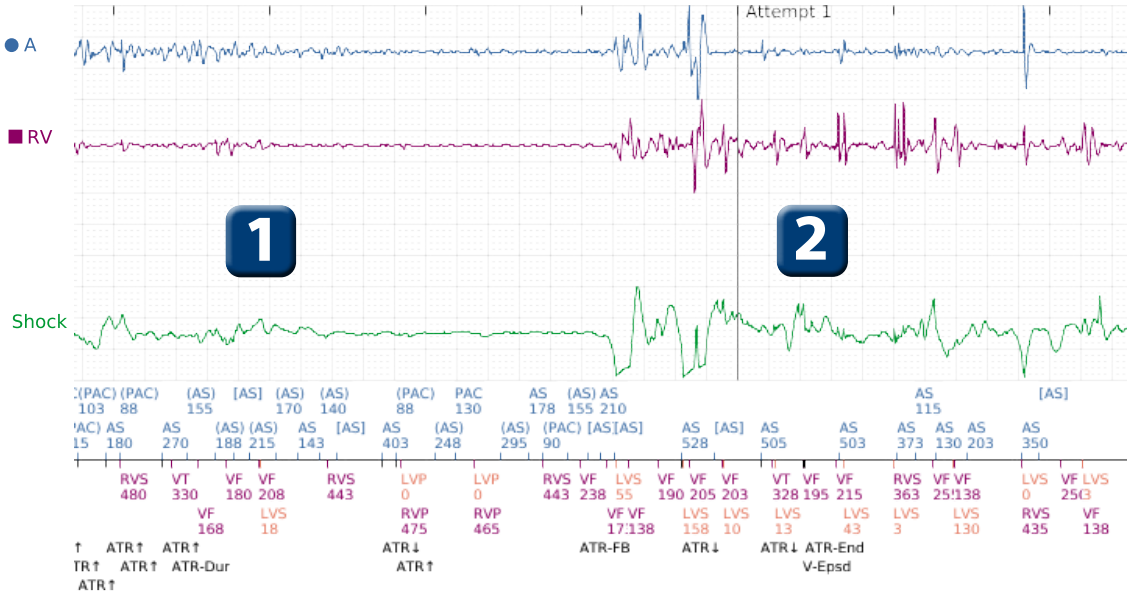
Summary

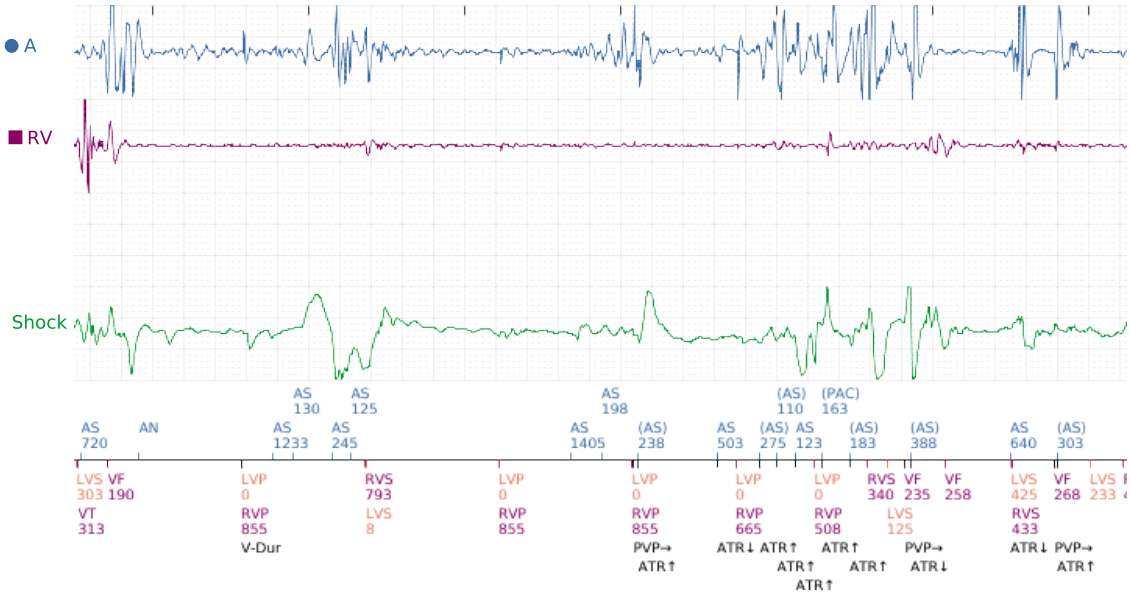
- detection of an episode in the VF zone
- no therapy delivered (device not programmed for monitoring + treatment)

EGM layout

1 no atrial or ventricular activity visible on the 3 channels; baseline interference explains the sensing of intermittent signals on the atrial and ventricular channels

2 simultaneous sensing on the 3 channels (atrial, ventricular, shock) of fast, chaotic signals of variable amplitude and morphology (classified as AF, VF) when electrocautery is used by the surgeon.


Attempt 1
A
RV
1
2
Shock


A
RV
Shock

Patient 2

- male implanted with an Autogen triple-chamber defibrillator; cardiac surgery (coronary bypass); trace recorded during the procedure

Summary

- detection of an episode in the VF zone
- electric shock of 41 Joules

EGM layout

1. simultaneous detection of fast, chaotic signals of variable amplitudes and morphology on the ventricular and shock channels (electrocautery)
2. end of oversensing
3. onset of a very rapid, low voltage ventricular arrhythmia; imperfect ventricular sensing
4. detection of a VF episode and capacitor charging
5. electric shock of 41 Joules
6. termination arrhythmia

V-16: 29 Apr 2021 08:43, VF, A Rate: 30 min^{-1}, V Rate: 264 min^{-1}

Detail

VF Event Onset

Avg A Rate	30 min^{-1}
Avg V Rate	264 min^{-1}
Detection	Rate Only
Template	N/R

At V-Detect

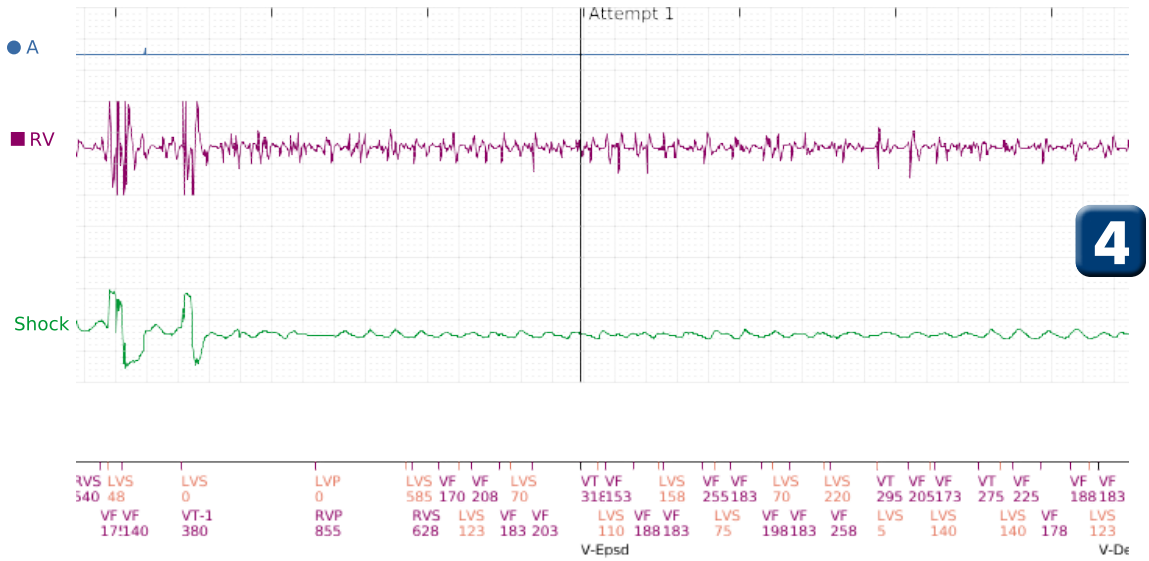
Avg A Rate	30 min^{-1}
Avg V Rate	311 min^{-1}
Rate Zone	VF
Stability	(45 ms, Off)
V>A Rate	(True, Off)
AFib	(False, Off)
RhythmMatch™	N/R
SRD Met	(False, Off)
ATP Timeout	False
Onset Intvl	(330 ms, Off)
Onset %	(44 %, Off)

Attempt 1, 41 J V Shock

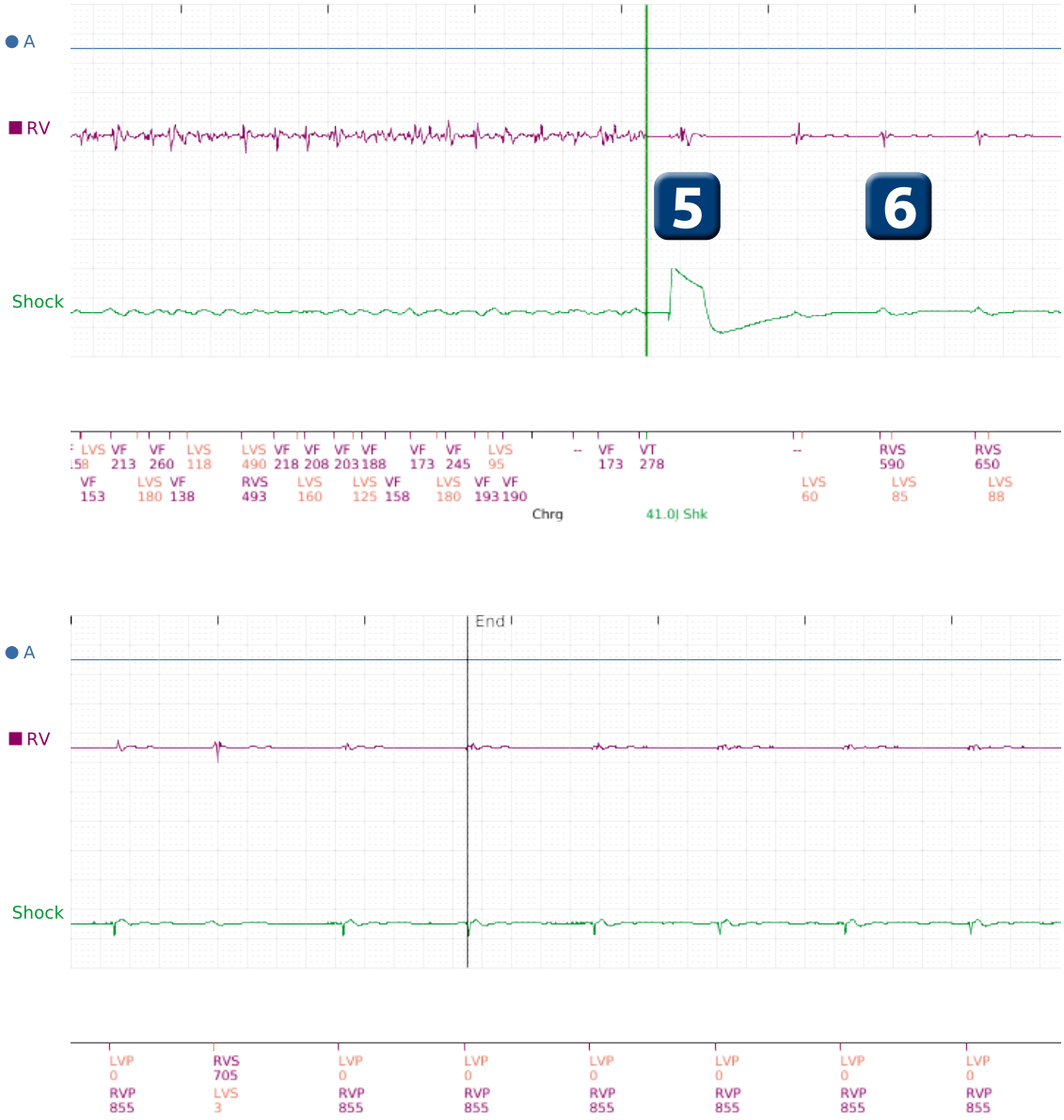
Elapsed Time	00:00:03
Shock Information	
Charge Time	10.0 s
Lead Impedance	67 Ω
Lead Polarity	Initial

Event Ended 00:00:46

EGM displayed at 25mm per second


Attempt 1
A
RV
Shock
4
V-Epsd

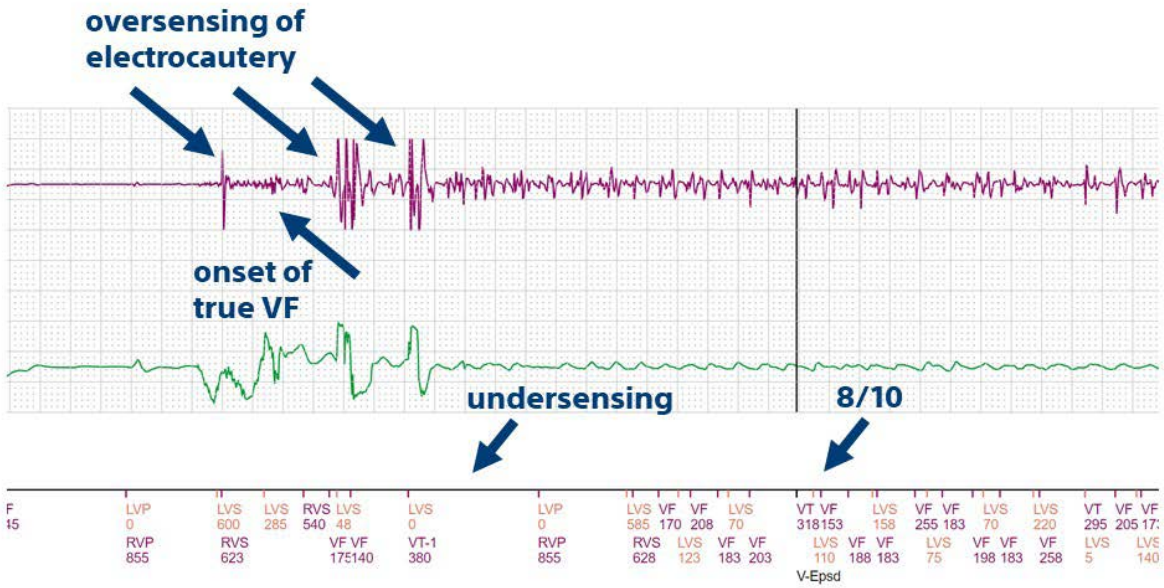

A
RV
Shock
Chrg



Points to remember

- these 2 patients underwent cardiac surgery with extra-corporeal circulation; for the first patient, the Tachy Mode was programmed to monitor only during the procedure, for the second to monitoring + treatment; it is usual to program the Tachy Mode to off, with any bradycardia or tachycardia occurring during the procedure being managed by temporary pacing or external cardioversion respectively.

- the first tracing shows a characteristic appearance of cardioplegia (asystole despite the pacing delivered by the defibrillator); this technique, which aims to stop the activity of the heart during the operation, is carried out by injecting a liquid very rich in potassium directly into the coronary arteries; this makes it possible to carry out the surgical procedure on immobile organs; the first tracing shows, overlying this flat background trace, the oversensing of characteristic signals related to the use of electrocautery by the surgeon
- the second trace shows the detection and termination of a true VF episode by a shock delivered by the device; this arrhythmia occurs during reperfusion at the end of the operation, which is relatively frequent and is usually managed by the anesthetic team with external defibrillation, the implantable device having been deprogrammed before the operation.



This figure shows the characteristic appearance of cardioplegia followed by oversensing of electrocautery and then the onset of true VF.

3 Inappropriate therapies during a TAVI procedure

Patient

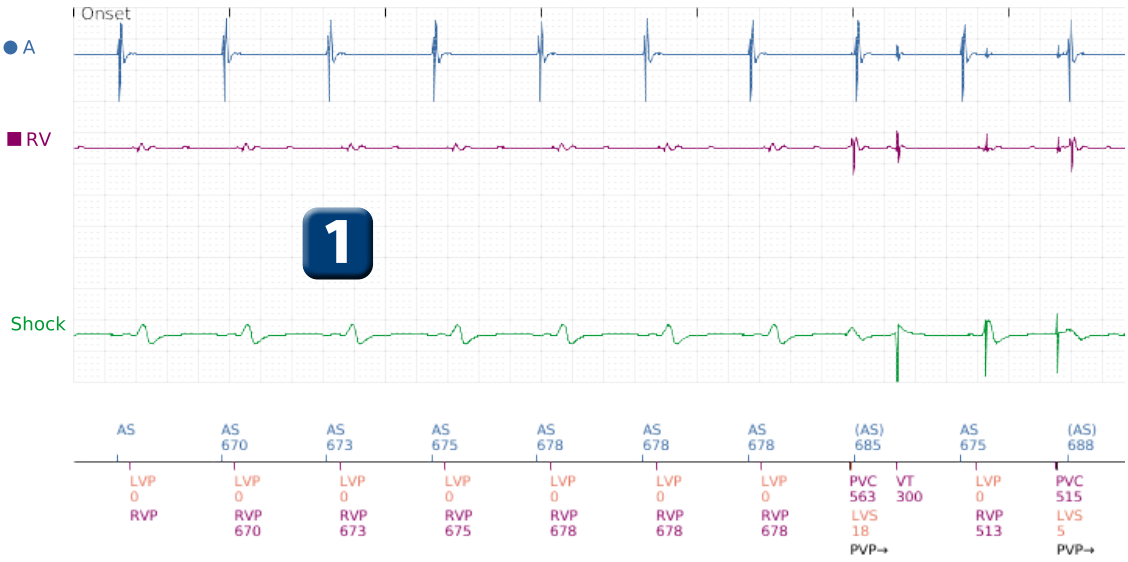
- hmale implanted with a Resonate triple-chamber defibrillator; trace recorded during a TAVI implantation procedure. The surgery may be called a transcatheter aortic valve replacement (TAVR) or transcatheter aortic valve implantation (TAVI).

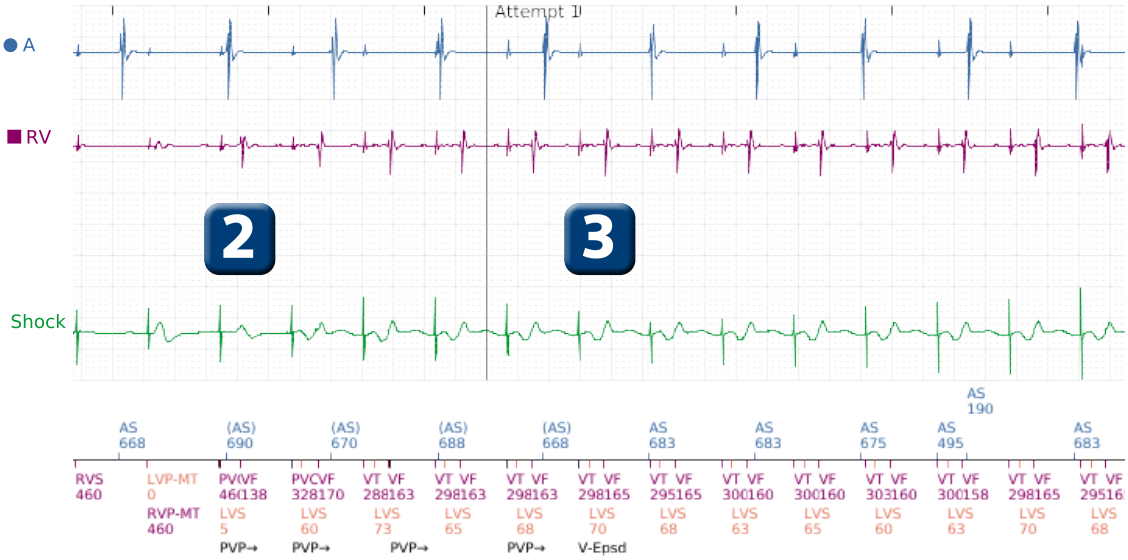
Summary

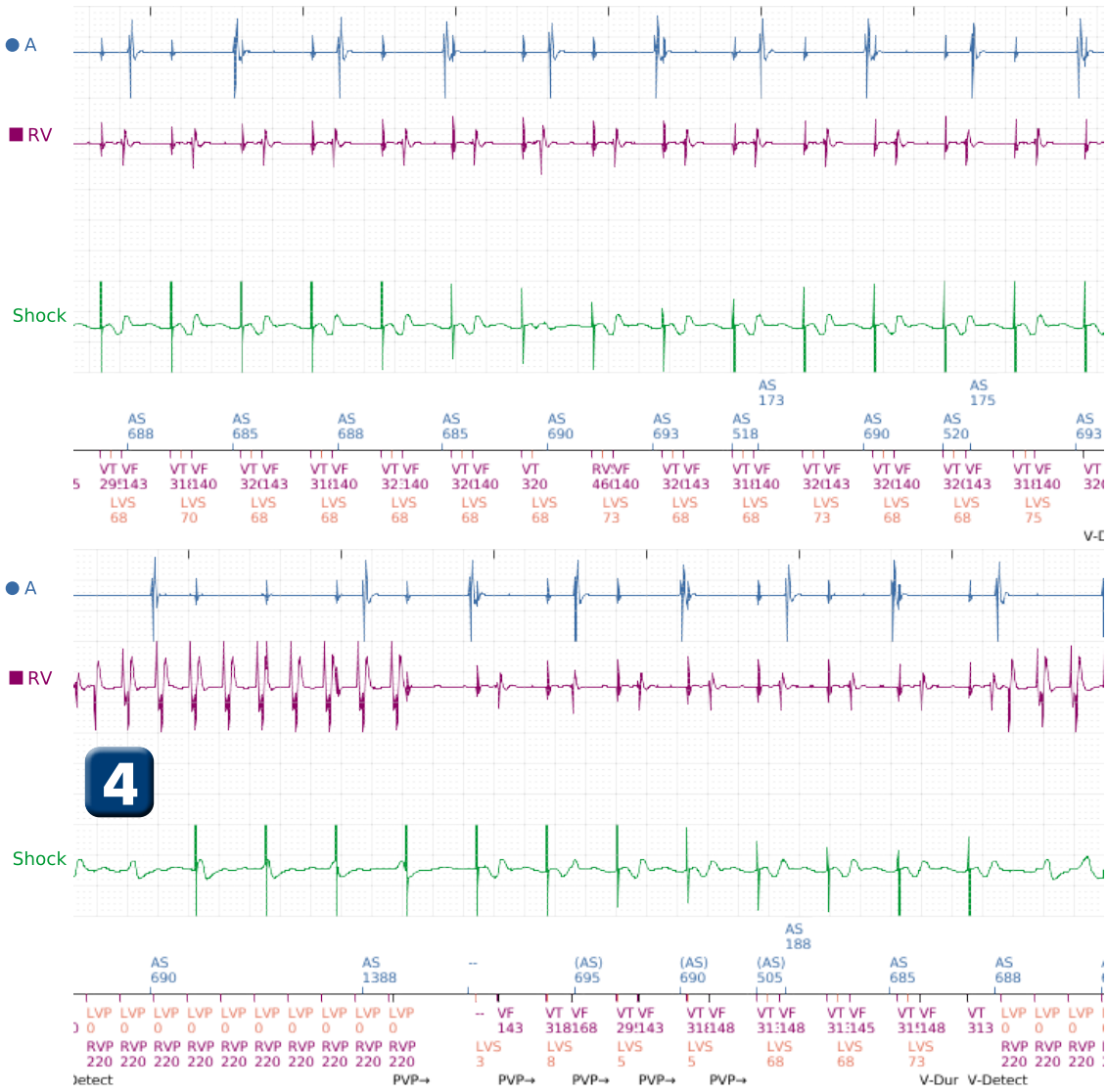
- detection of an episode in the VT zone
- sequence of bursts then ramps; 41 Joule shock but deflected impact

EGM layout

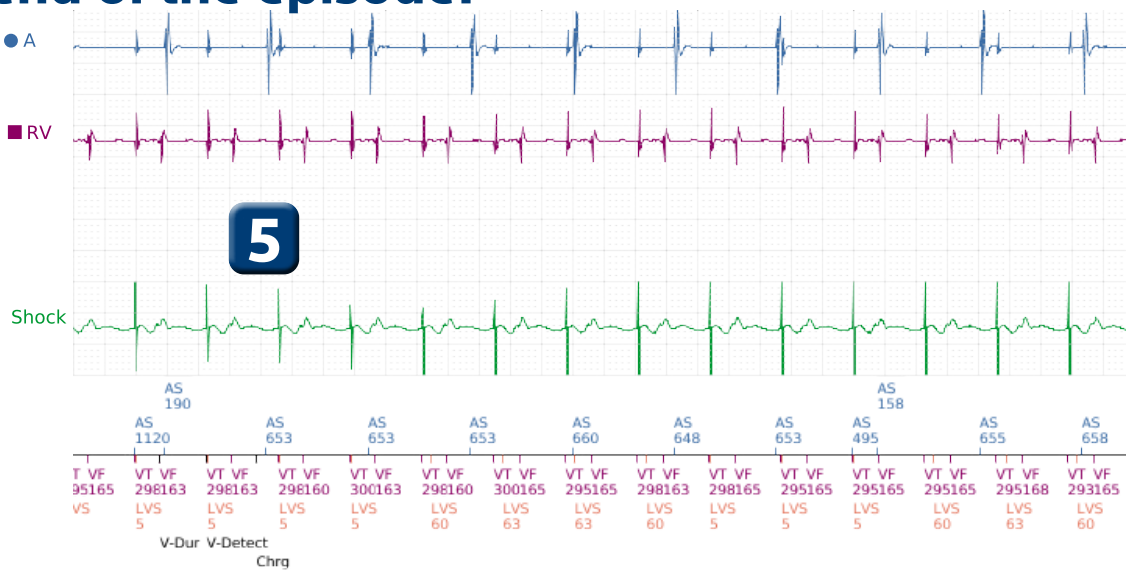
1. atrial sensing and biventricular pacing
2. sensing of a sharp signal on the 3 channels (atrial, ventricular and shock); this signal corresponds to the ventricular pacing artefact (ventricular capture visible on the shock channel); double counting on the ventricular sensing channel (pacing artefact + subsequent ventricular depolarization).
3. alternating VT and VF cycles; the 8/10 criterion is fulfilled for the VT zone but not for the VF zone.
4. end of duration for VT zone and first ATP sequence delivered
5. after the ATP sequences, the next therapy is a shock; capacitors begin to charge
6. pacing interrupted and cessation of oversensing
7. charge diverted (criterion 2/3 rapid cycles at end of charge not confirmed)

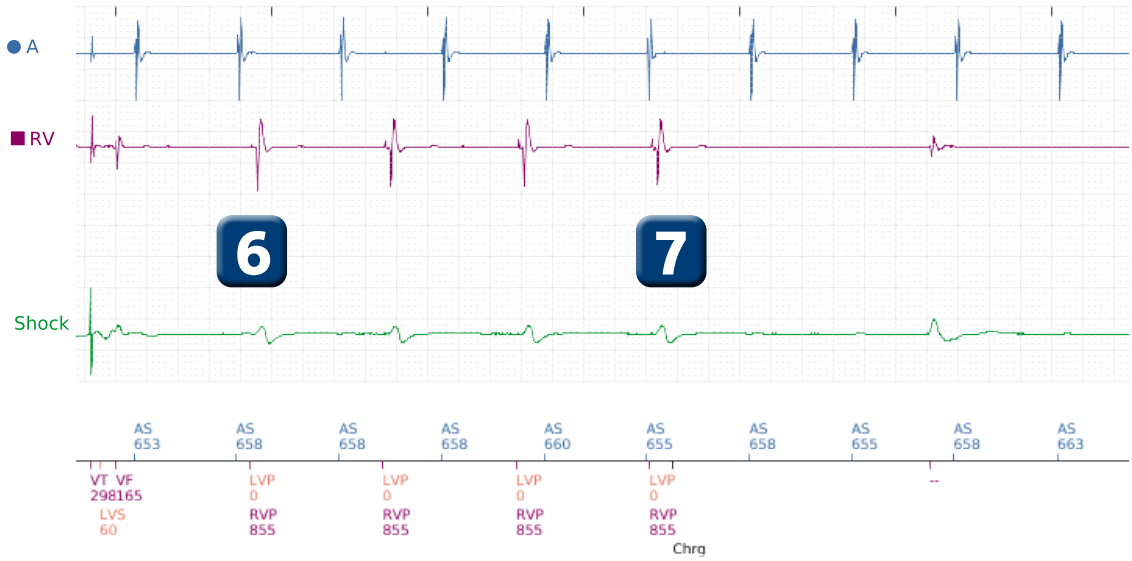

Onset
A
RV
1
Shock
AS AS AS AS AS AS AS (AS) AS (AS)
670 673 675 678 678 678 685 675 688
LVP LVP LVP LVP LVP LVP LVP PVC VT LVP PVC
0 0 0 0 0 0 0 563 300 0 515
RVP RVP RVP RVP RVP RVP RVP LVS LVS RVP LVS
670 673 675 678 678 678 18 513 5
PVP→ PVP→


Attempt 1
A
RV
2
3
Shock
AS AS (AS) (AS) (AS) (AS) AS AS AS AS AS AS
190
668 690 670 688 668 683 683 675 495 683
RVS LVP-MT PVCVF PVCVF VT VF VT VF VT VF VT VF VT VF VT VF VT VF VT VF VT VF VT VF
460 0 460138 328170 288163 298163 298163 298165 295165 300160 300160 303160 300158 298165 295168
RVP-MT LVS LVS LVS LVS LVS LVS LVS LVS LVS LVS LVS LVS LVS
460 5 60 73 65 68 70 68 63 65 60 63 70 68
PVP→ PVP→ PVP→ PVP→ V-Epsd



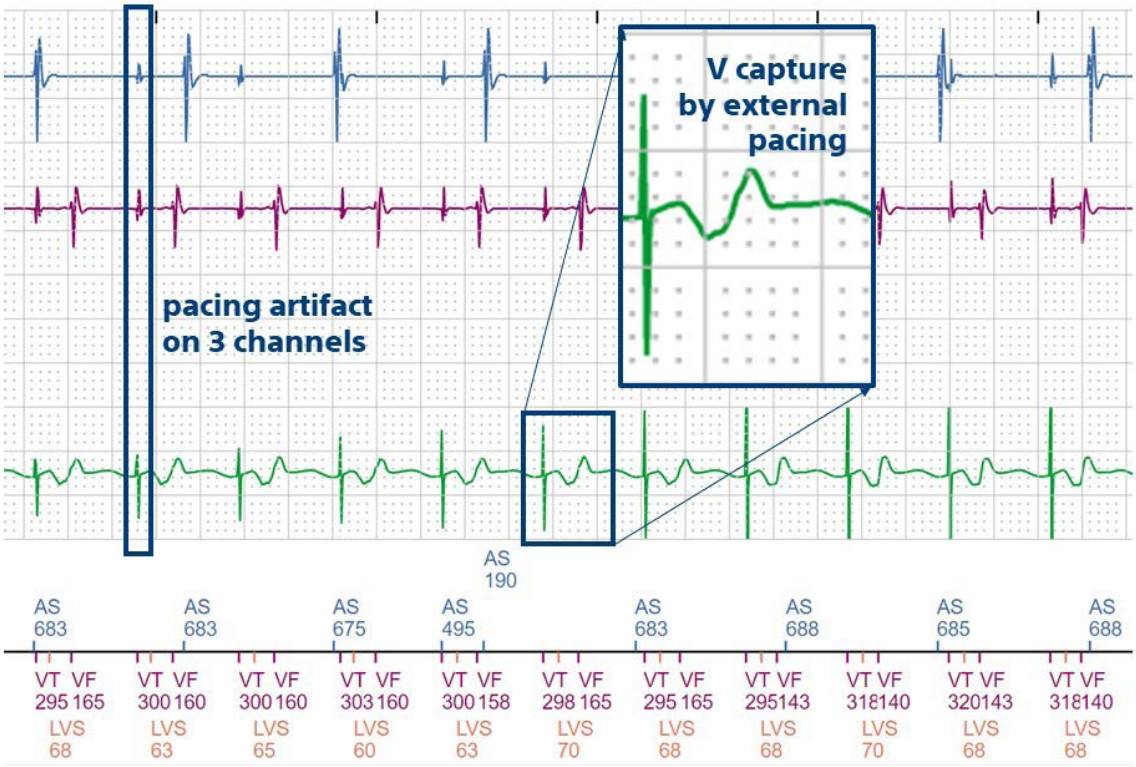
part of the episode is not displayed, end of the episode:





Points to remember

- aortic stenosis is the most common valvular disease encountered in Western countries, with an estimated prevalence of around 5% among people aged over 75; with an ageing of the population, the prevalence is likely to increase further
- since the first percutaneous aortic valve implantation 2002, the indications for TAVI (transcatheter aortic valve implantation) have broadened considerably, resulting in an increase in the number of procedures performed worldwide.
- during the TAVI implantation procedure, rapid ventricular pacing is usually delivered using a temporary lead positioned in the right ventricle to induce severe, but transient hypotension in order to reduce the risk of embolization of the prosthesis
- during a TAVI implantation procedure, the implantable defibrillator must be temporarily deprogrammed in order to avoid the occurrence of inappropriate therapies (sensing of pacing artefact, rapid ventricular rhythm, etc.).
- this type of epiode will typically trigger an optional Lattitude alert «Non physiological right ventricular signal detected» through. because of atleast 4 fast ventricular cycles (<=160ms) before the V-Detect marker.



This figure shows the pacing artefact on all 3 channels and ventricular capture on the shock channel during external pacing

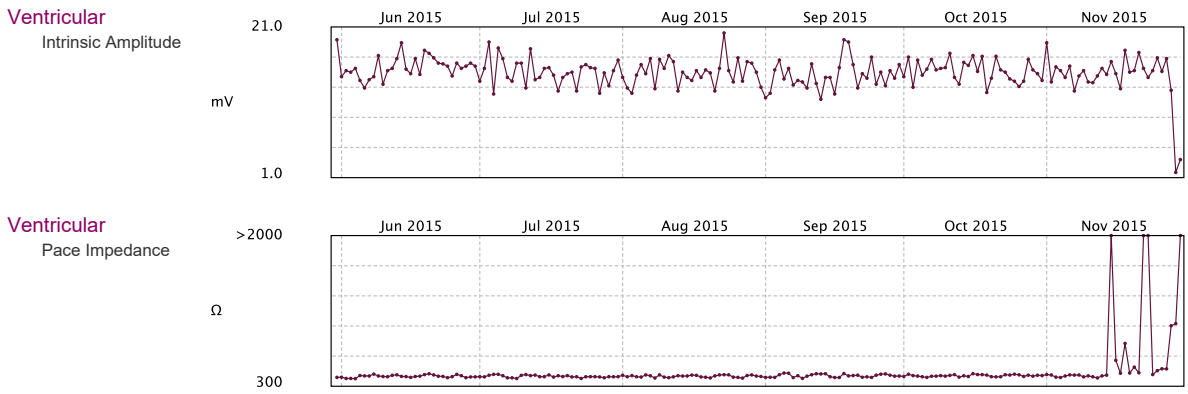
4 Lead fracture and multiple capacitor charges

Patient

- 60-year-old male implanted with an Incepta single-chamber defibrillator; telemedicine alert for abnormal impedance measurement

Courbes de détection et d'impédances

- stable right ventricular shock impedance
- abnormal right ventricular pacing impedance (> 2000 Ohms)
- the impedance curve shows a number of abnormal values and a clear jump when compared to previously stable values



Episode list since previous interrogation

- multiple episodes of non-sustained VT recorded at the same time as the abnormal pacing impedance values
- 2 episodes classified as VT with no therapy delivered

All Events Since Last Reset (30 May 2014)

29 Nov 2015 18:56	NonSustV at 160 min^{-1}, Nonsustained
29 Nov 2015 16:32	NonSustV at 157 min^{-1}, Nonsustained
29 Nov 2015 13:56	NonSustV at 231 min^{-1}, Nonsustained
29 Nov 2015 07:32	NonSustV at 239 min^{-1}, Nonsustained
28 Nov 2015 21:05	NonSustV at 180 min^{-1}, Nonsustained
28 Nov 2015 16:25	NonSustV at 139 min^{-1}, Nonsustained
28 Nov 2015 07:56	NonSustV at 213 min^{-1}, Nonsustained
28 Nov 2015 06:12	NonSustV at 170 min^{-1}, Nonsustained
27 Nov 2015 11:09	NonSustV at 207 min^{-1}, Nonsustained
27 Nov 2015 10:56	NonSustV at 212 min^{-1}, Nonsustained
27 Nov 2015 06:49	VT at 341 min^{-1}, No Therapy
25 Nov 2015 18:32	VT at 283 min^{-1}, No Therapy

Total Events: 97 NonSustV, 2 Other Untreated

Episode summary

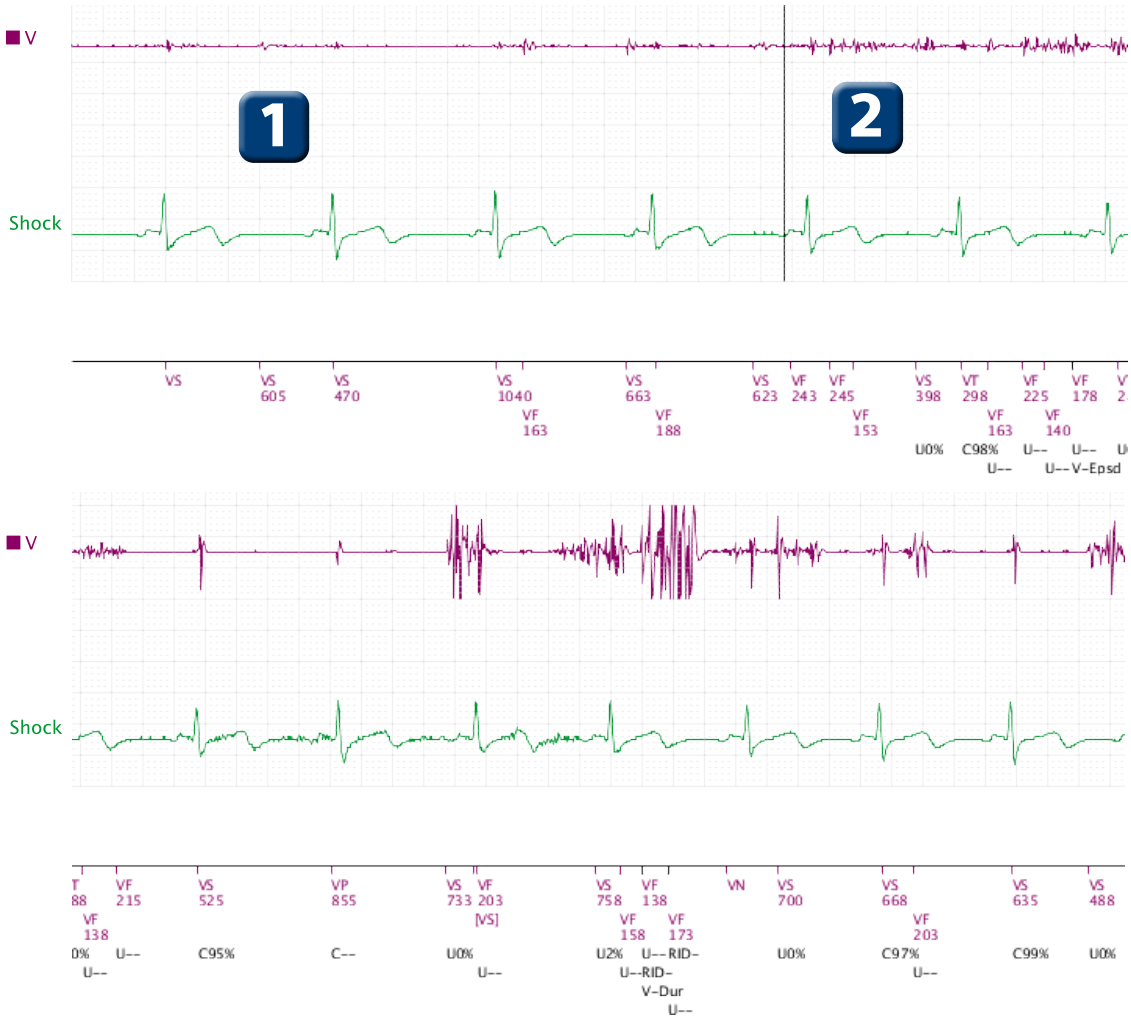
- episode classified in the VT zone
- no therapy delivered

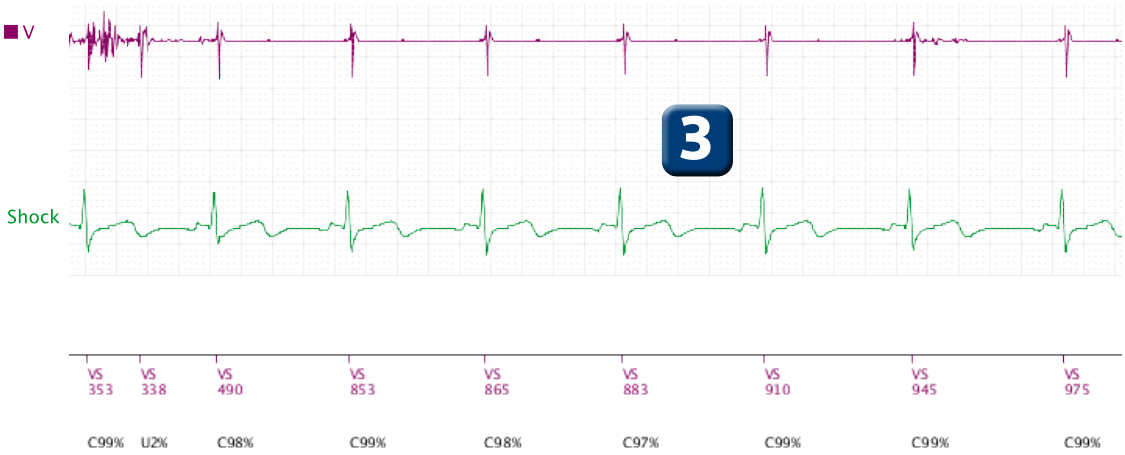
EGM layout

1 oversensing of fast signals on the bipolar sensing channel; no oversensing on the shock channel

2 oversensing on the ventricular channel of signals of variable amplitude and morphology; occasional large amplitude signals saturating the amplifiers; the shock channel makes it possible to differentiate these signals from spontaneous ventricular activity

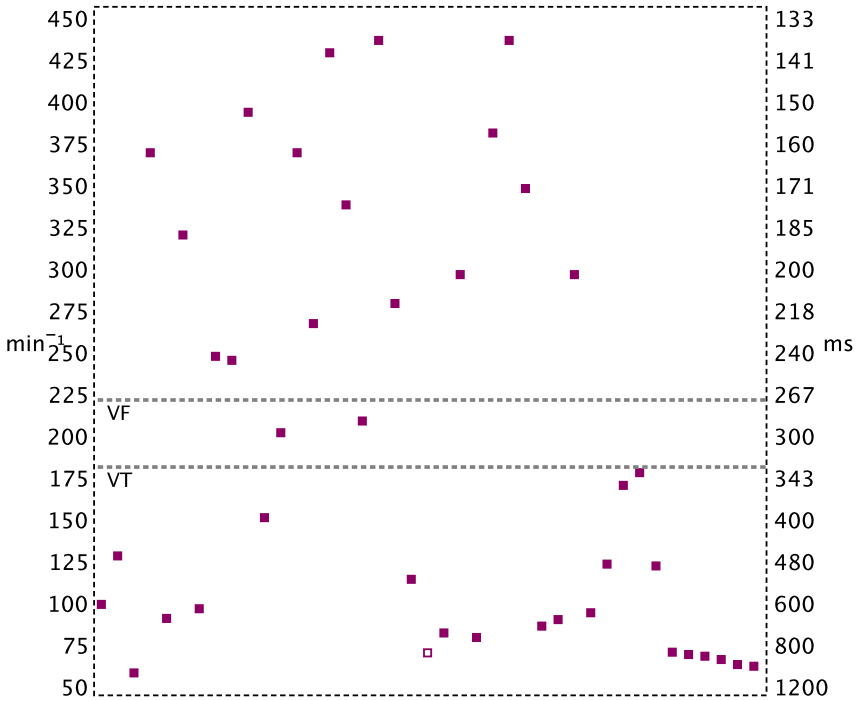
3 end of oversensing





Interval plot

- appearance suggestive of lead dysfunction; the presence of a cloud of points that is generally incompatible with ventricular arrhythmia
- very fast cycles (bordering on blanking) with slower cycles



The interval plot is suggestive of lead dysfunction with a cloud of points appearance: highly variable ventricular cycle lengths, very short cycles at the limit of ventricular blanking after ventricular sensing, etc.

Points to remember

- the defibrillation lead is the weak link in the defibrillation system, with rates of malfunction varying between models
- in this patient, the combination of high impedance values and the abnormal EGM trace is highly suggestive of lead fracture; there is oversensing of fast, intermittent signals of varying morphology with very short cycle lengths close to the ventricular blanking period; some signals are very large, saturating the amplifiers; these 'make-break' potentials are highly suggestive of lead fracture with probable breach of the conductor rather than an insulation defect; the graph also shows a characteristic cloud of points with very short cycles
- in this asymptomatic patient, remote monitoring facilitated an early diagnosis and prevented inappropriate therapies; this helps avoids a succession of inappropriate shocks which, even if diverted, consume energy and shorten the life of the device
- in cases of lead dysfunction, anomalies generally occur in different stages: initially, the device may record multiple episodes of non-sustained VT without any anomalies in lead parameters; subsequently, a clear break in impedance, threshold and right ventricular sensing curves may be observed; as the duration of over-sensing episodes increases, multiple shocks may occur

5 Oversensing of the P wave by the defibrillation lead

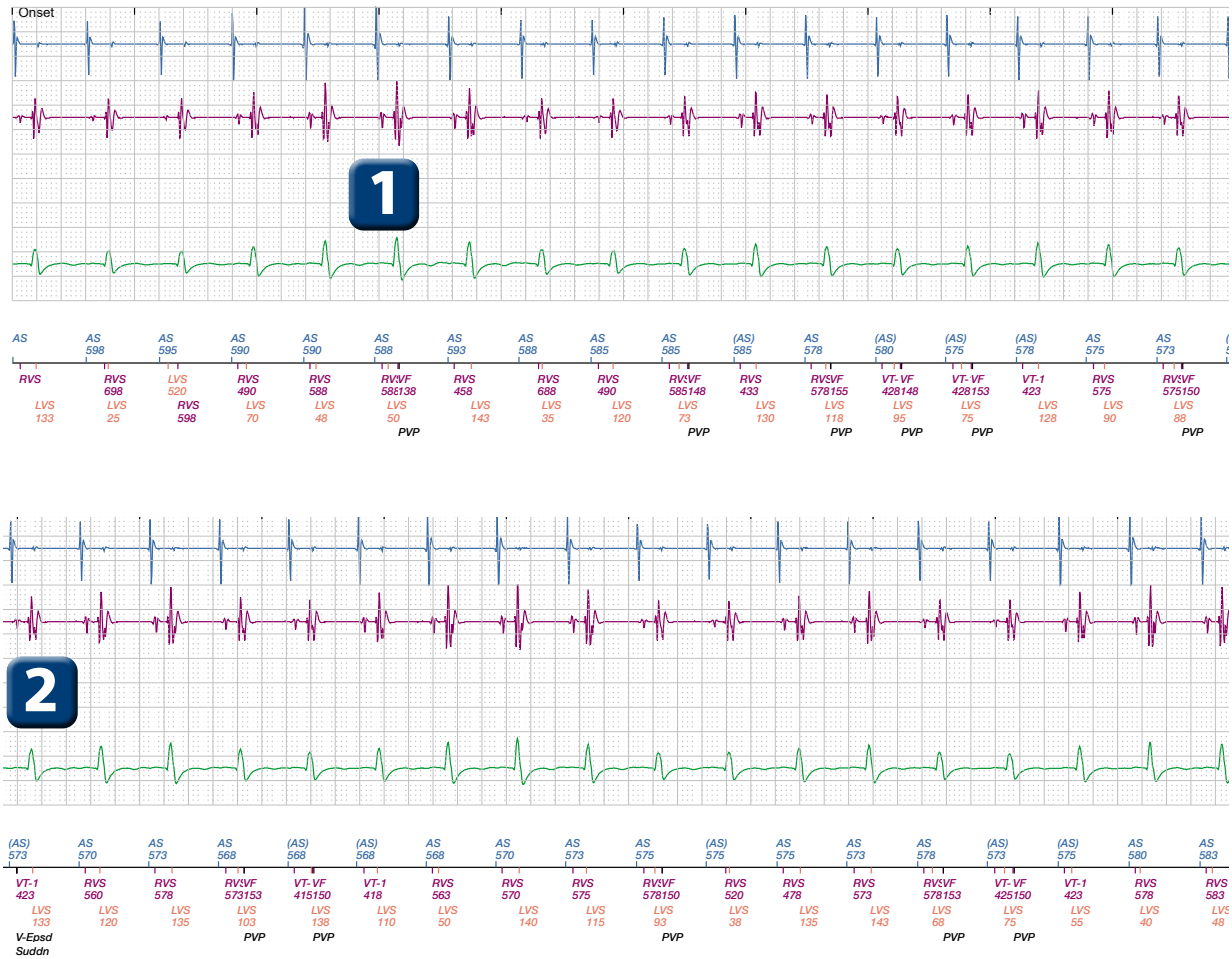
Patient

- male implanted with a triple-chamber defibrillator; recording of a NSVT trace

EGM layout

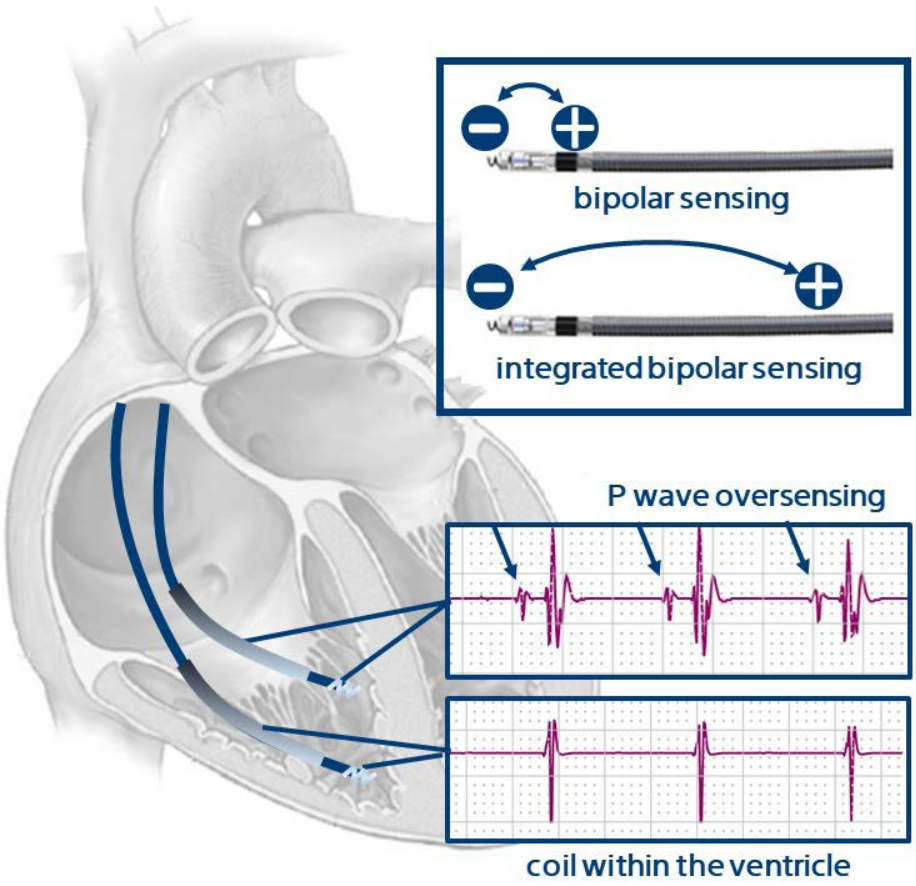
1 intermittent oversensing of atrial activity by the right ventricular lead (clearly visible on the atrial channel); some cycles classified as VS, VT-1, VT or VF

2 8/10 criterion fulfilled for the VT-1 zone



Points to remember

- this trace shows sinus tachycardia with intermittent oversensing of atrial activity by the defibrillation lead
- oversensing of atrial signals by the ventricular lead tends to occur in 2 situations: 1) displacement of the right ventricular lead at the atrio-ventricular junction (coincides with a decrease in the amplitude of the measured R wave); 2) positioning of an integrated bipolar lead close to the tricuspid annulus, with the distal coil straddling the valve (coincides with a preserved amplitude of the R wave); Boston Scientific devices are potentially more prone to this type of problem insofar as they are frequently connected to an integrated bipolar lead.
- Atrial oversensing can also occur under more exceptional circumstances: 1) unintentional placement of a right ventricular lead in the coronary sinus; 2) insulation defect in the atrial portion of the ventricular lead leading to oversensing of atrial activity; 3) interaction between the atrial lead and the right ventricular lead, the atrial lead coming into contact with the ventricular lead and generating a signal at the moment of atrial systole.
- several solutions can be implemented to solve the problem and avoid the occurrence of inappropriate therapies or ventricular pauses in pacing-dependent patients with P wave oversensing: 1) reduce the ventricular sensitivity so as to eliminate the supernumerary signal linked to the oversensing of atrial activity; since this programming change is accompanied by an increased risk of under-sensing VF, an induction can then be undertaken to check that the induced VF is correctly sensed with this new sensitivity value; 2) in a significant number of cases, oversensing of atrial activity requires the defibrillation lead to be repositioned (new defibrillation lead for a DF4 system or addition of a pace/sense lead for a DF1 system).



Schematic explaining integrated bipolar sensing and showing how a right ventricular coil can straddle the tricuspid valve and lead to P wave oversensing.

6 Oversensing of atrial activity by the defibrillation lead during an episode of atrial arrhythmia

Patient

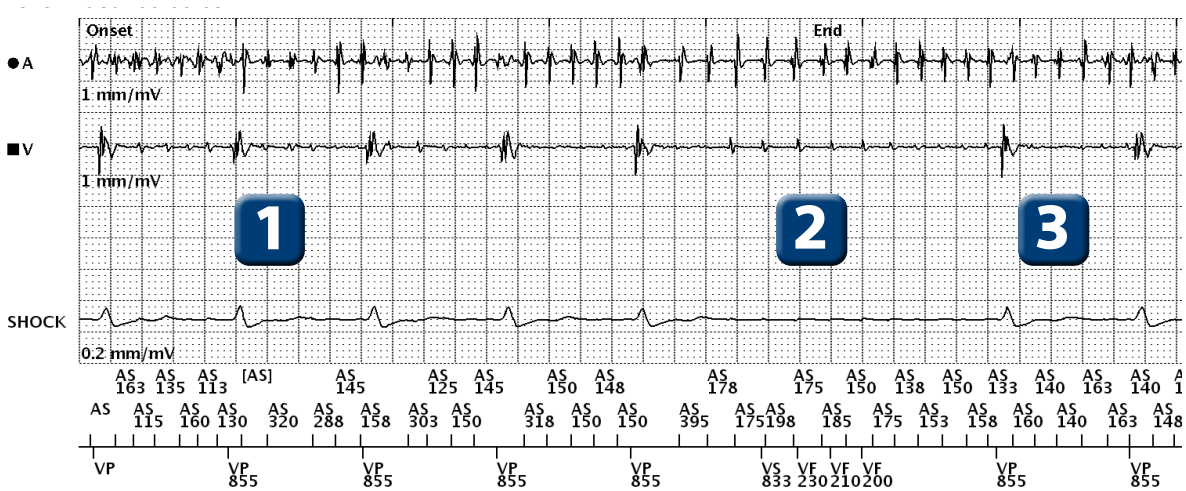
- 53-year-old male implanted with a Teligen dual-chamber defibrillator for dilated cardiomyopathy and complete atrioventricular block with an integrated bipolar ventricular lead (the anode of the sensing circuit is the defibrillation coil of the RV lead); repeated sensation of presyncope; alert received via telemedicine (Latitude).

EGM layout

1 atrial fibrillation correctly detected by the defibrillator with ventricular pacing (VP-Sr) at the sensor indicated rate in this pacing-dependent patient; the defibrillator has mode-switched into VDIR mode

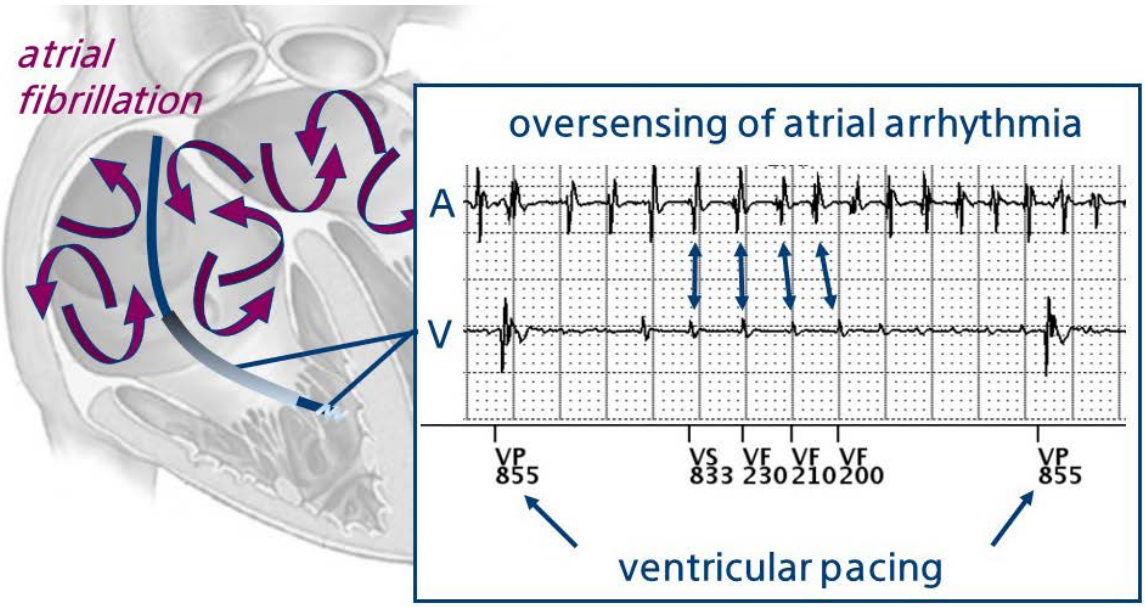
2 oversensing on the ventricular sensing channel; the shock channel confirms that this is not a ventricular arrhythmia; oversensing of rapid atrial activity results in a pause of just under 3 seconds which is responsible for the symptoms described.

3 end of oversensing



Points to remember

- this patient initially presented with complete atrioventricular block; oversensing of atrial arrhythmia by the ventricular sensing channel was responsible for a pause, the oversensed rapid rhythm inhibiting ventricular pacing; as a result, the patient developed recurrent presyncope in association with these types of episodes
- problems of oversensing are of particular concern in dependent patients, as they can lead to ventricular pauses and oversensing can be prolonged in the absence of spontaneous QRS complexes, with the level of sensitivity remaining at a maximum and adapted to the amplitude of the oversensed atrial signals, which is often low
- oversensing of an atrial arrhythmia can lead to both inappropriate therapy and asystole if the patient is pacing-dependent



This figure shows the oversensing of atrial arrhythmia by the ventricular lead and the concordance between the fast signals in the atrial and ventricular channels.

7 Early displacement of a right ventricular lead into the atrium

Patient

- male implanted with a Resonate triple-chamber defibrillator; shock from the device the day after implantation

Summary

- detection of an episode in an VF zone
- diverted 41 Joule shock, followed by delivery of a shock

EGM layout

1 atrial sensing and right ventricular sensing appear to be more or less simultaneous; left ventricular sensing occurs later and less frequently and probably corresponds to the true ventricular signal

2 onset of rapid, disorganized arrhythmia on the atrial channel; very rapid signals sensed simultaneously on the right ventricular channel (intermittent sensing)

3 sustained oversensing on the right ventricular channel

4 8/10 criterion satisfied for the VF zone

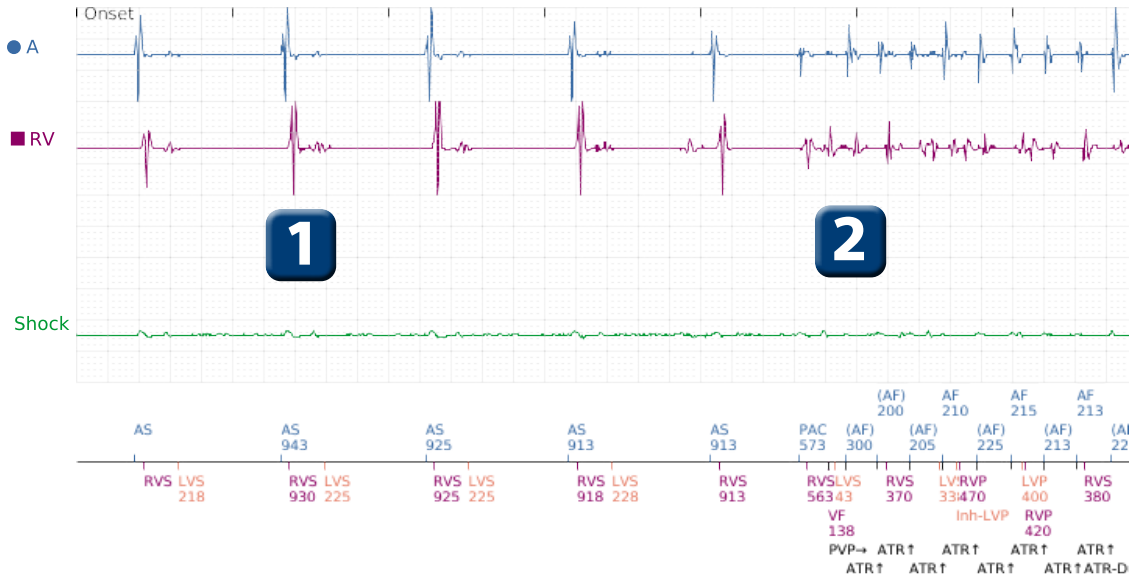
5 end of duration and start of capacitor charging

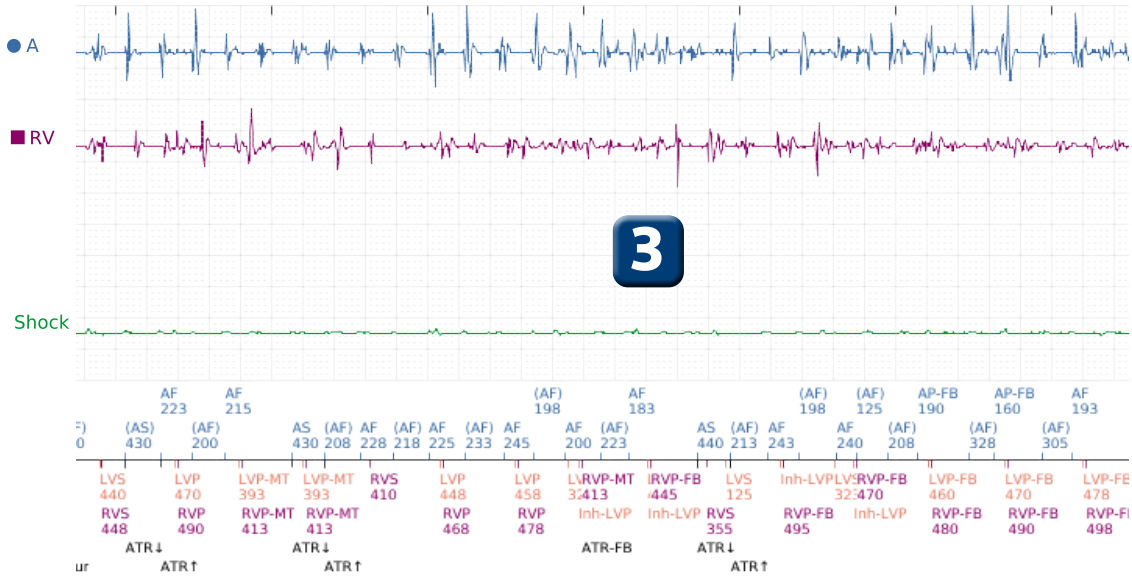
6 criterion 6/10 is no longer satisfied and the charge is diverted

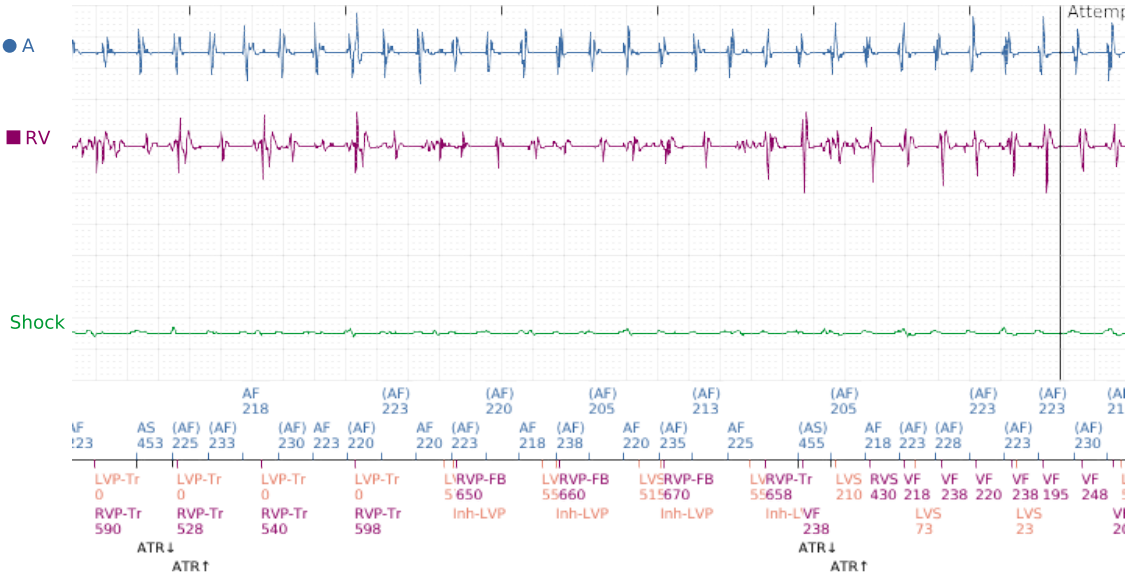
7 new capacitor charge; this charge cannot be diverted (only one charge can be diverted for a single episode)

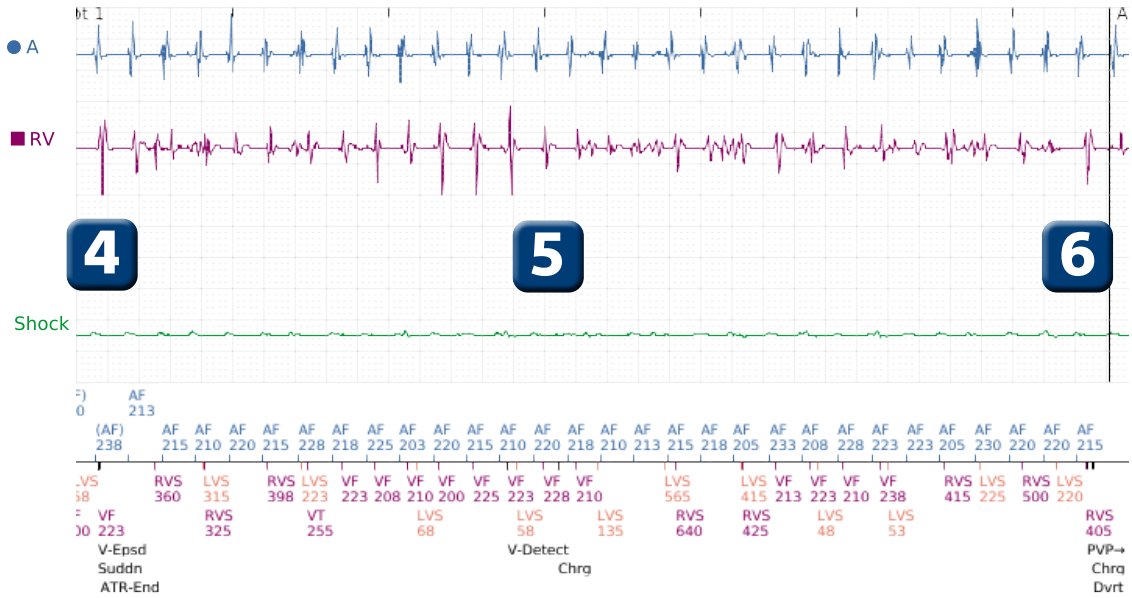
8 at end of charge after the 500 ms window, a shock is delivered

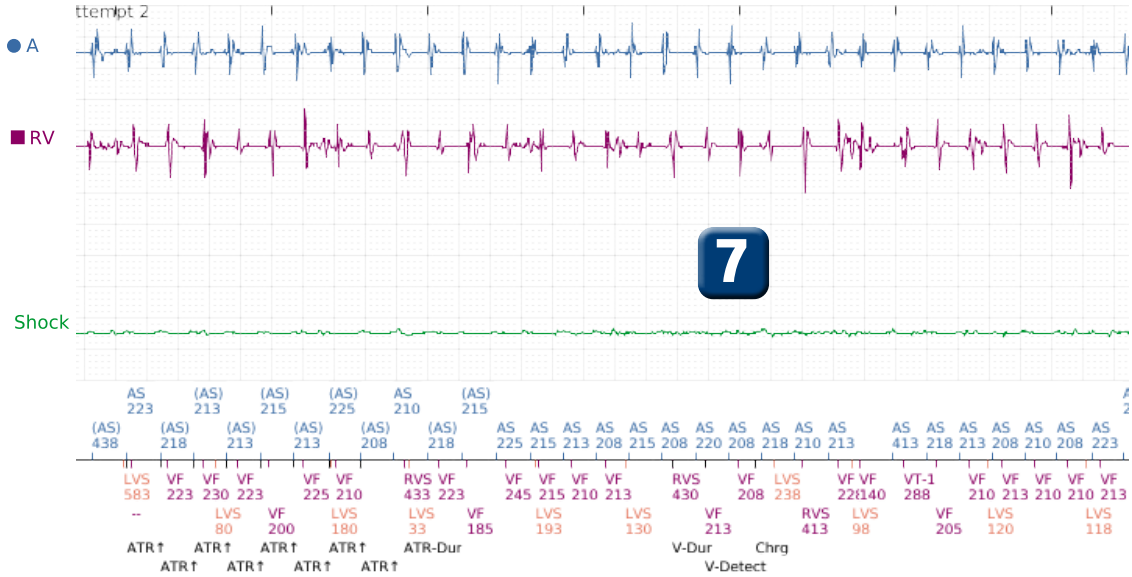
9 termination of atrial arrhythmia and cessation of oversensing



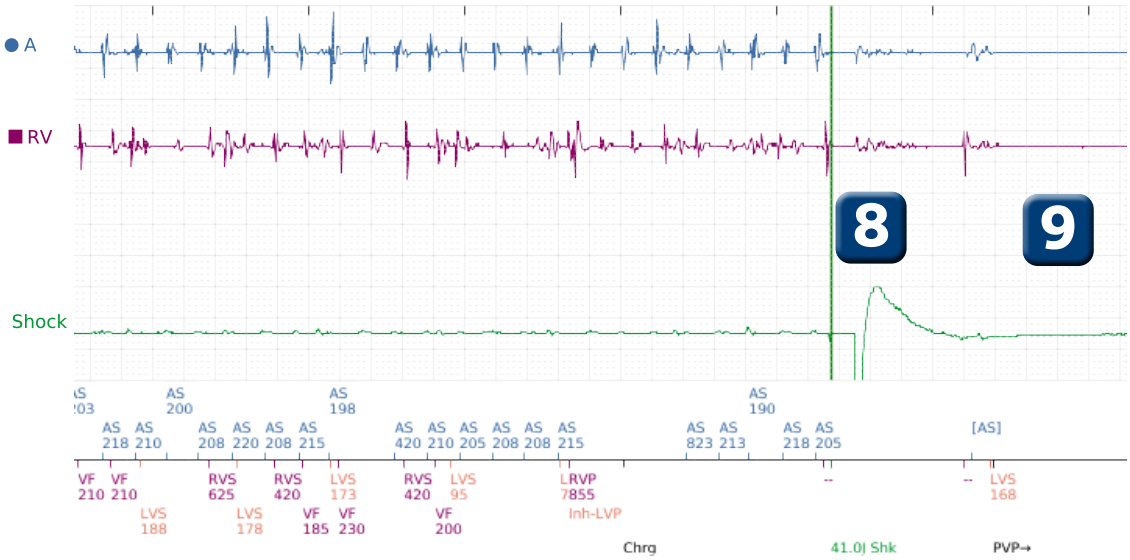


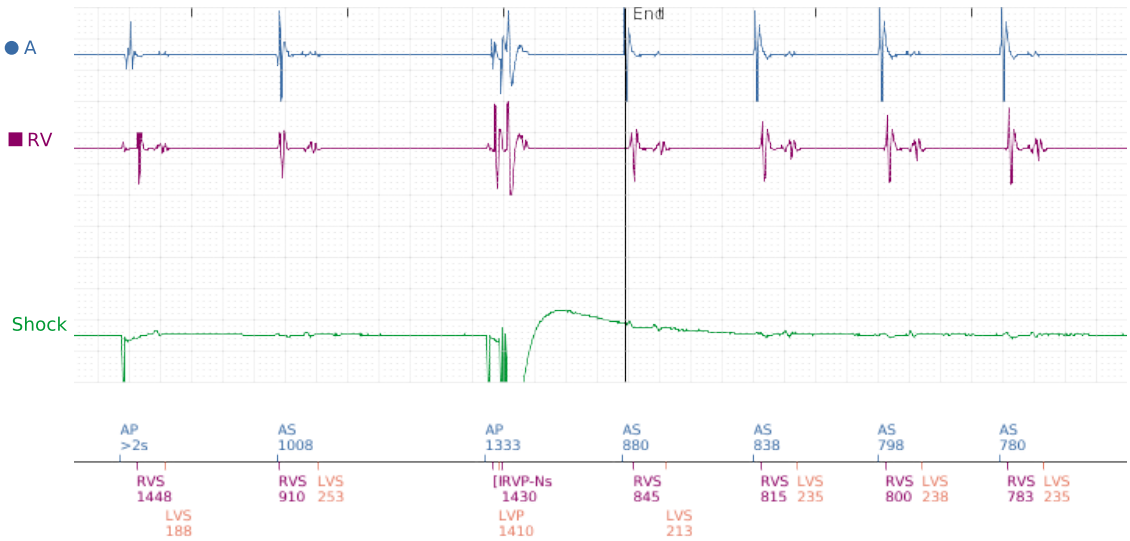






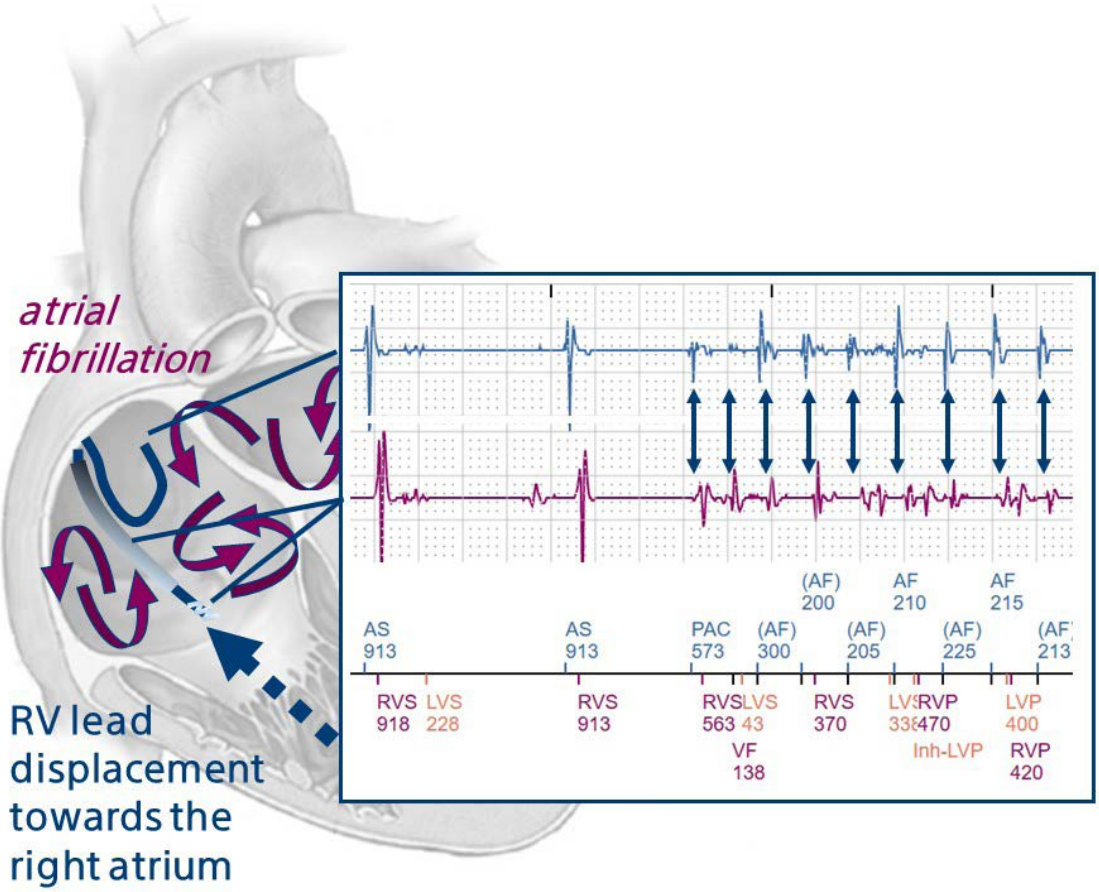
LATITUDE™ Patient Management - Event Detail Report 25 Jan 2023





Points to remember

- this pattern corresponds to early displacement of the defibrillation lead; the chest X-ray showed the lead floating in the atrium
- an inappropriate electric shock was delivered due to oversensing of an AF episode by the defibrillation lead
- while waiting for the lead to be repositioned, therapies were temporarily programmed off so as to avoid the occurrence of additional inappropriate therapies



This figure shows the oversensing of atrial arrhythmia by the ventricular lead and the concordance between the fast signals in the atrial and ventricular channels.

8 T wave oversensing

Patient

- 75-year-old man implanted with an Energen single-chamber defibrillator; episode recorded in device memory

EGM layout

1 sinus rhythm with intermittent T wave oversensing

2 prolonged oversensing and 8/10 criterion verified (V-Epsd)

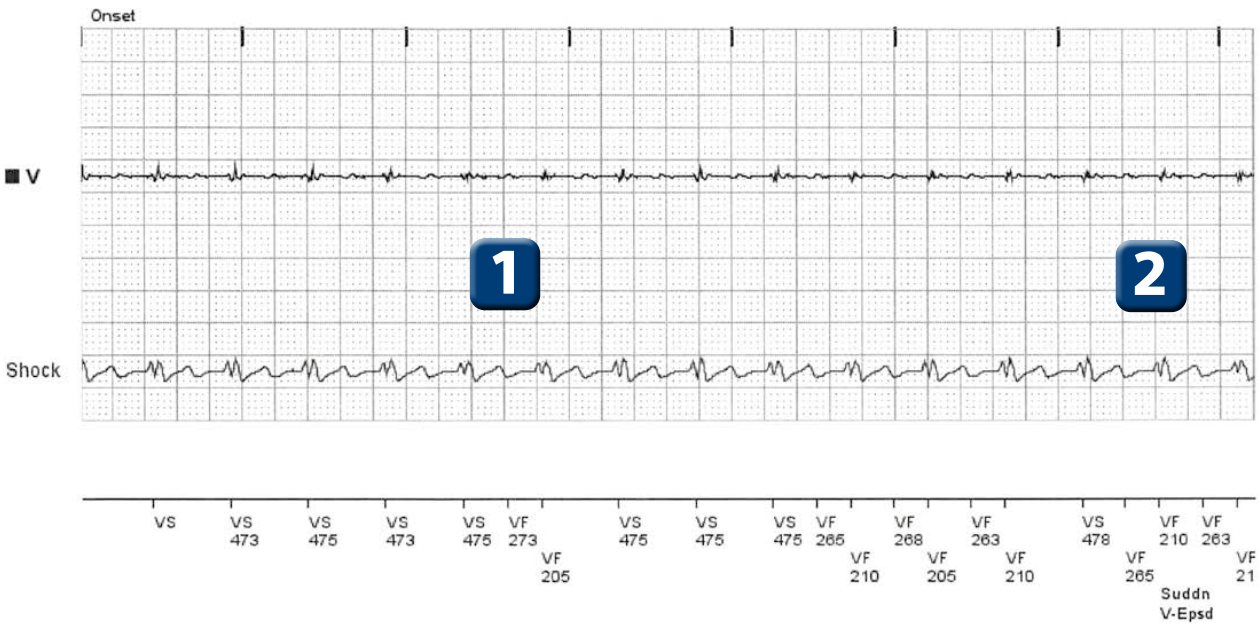
3 end of duration (1 second) and start of capacitor charging

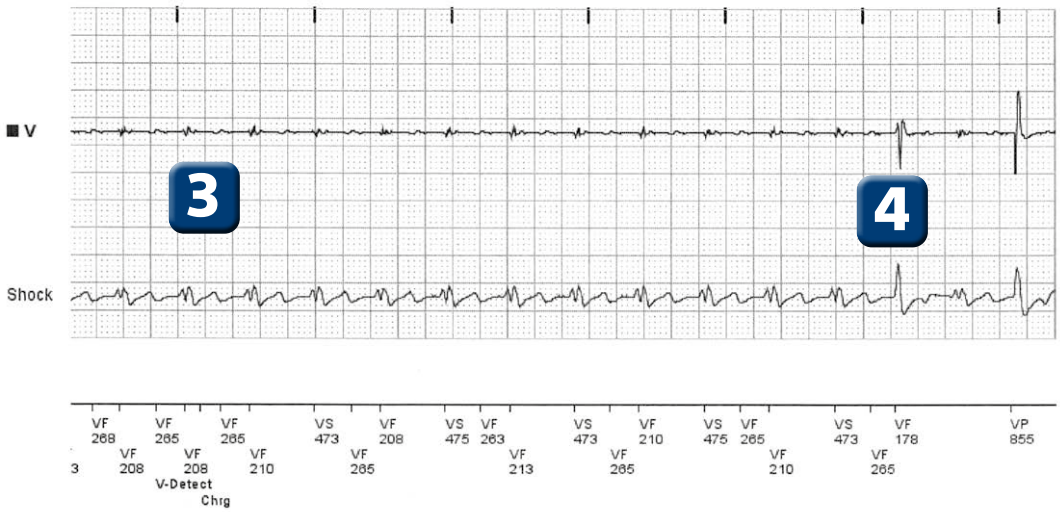
4 ventricular extrasystole and under- sensing of the following QRS complex

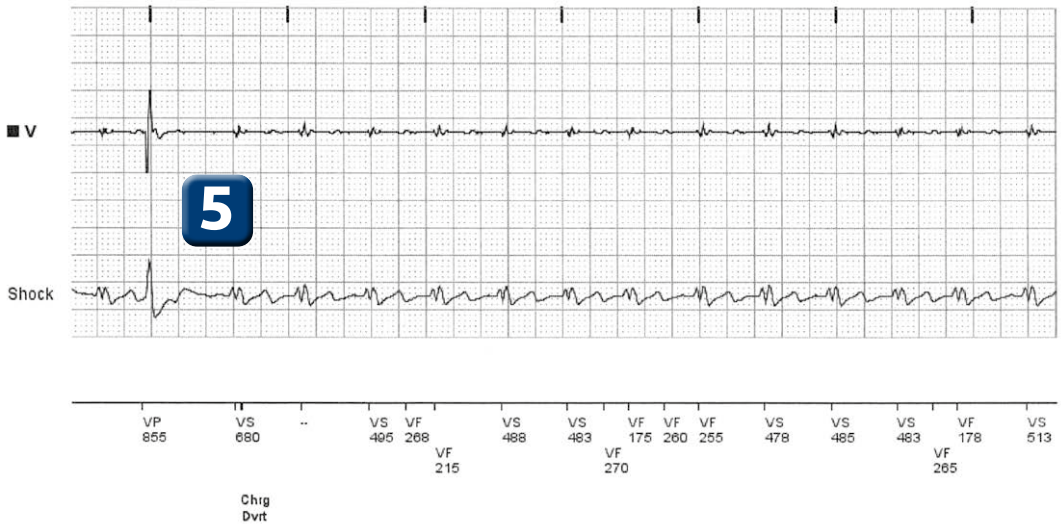
5 undersensing and interruption of charging

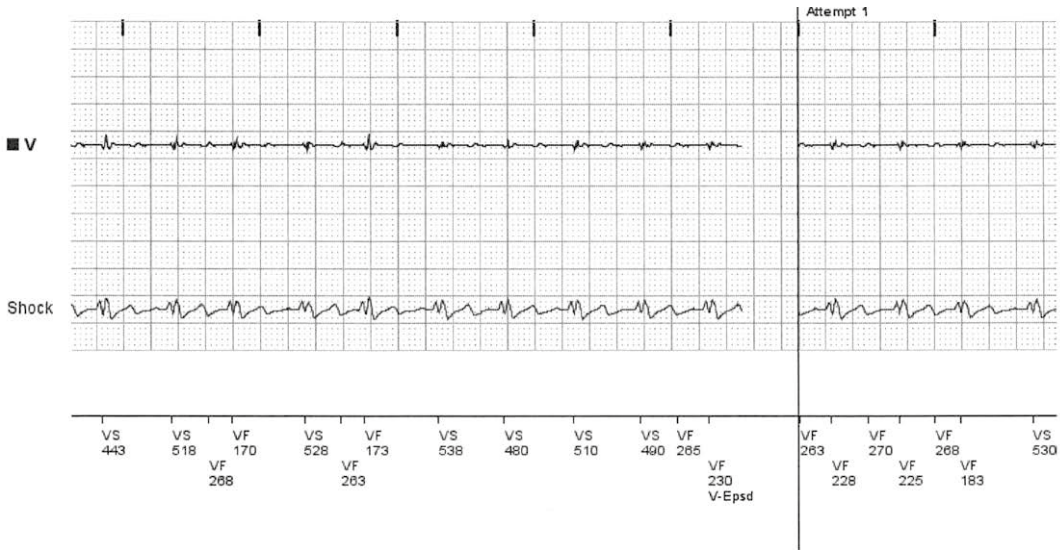
6 criterion 8/10 checked again; at the end of the duration, ATP Quick Convert

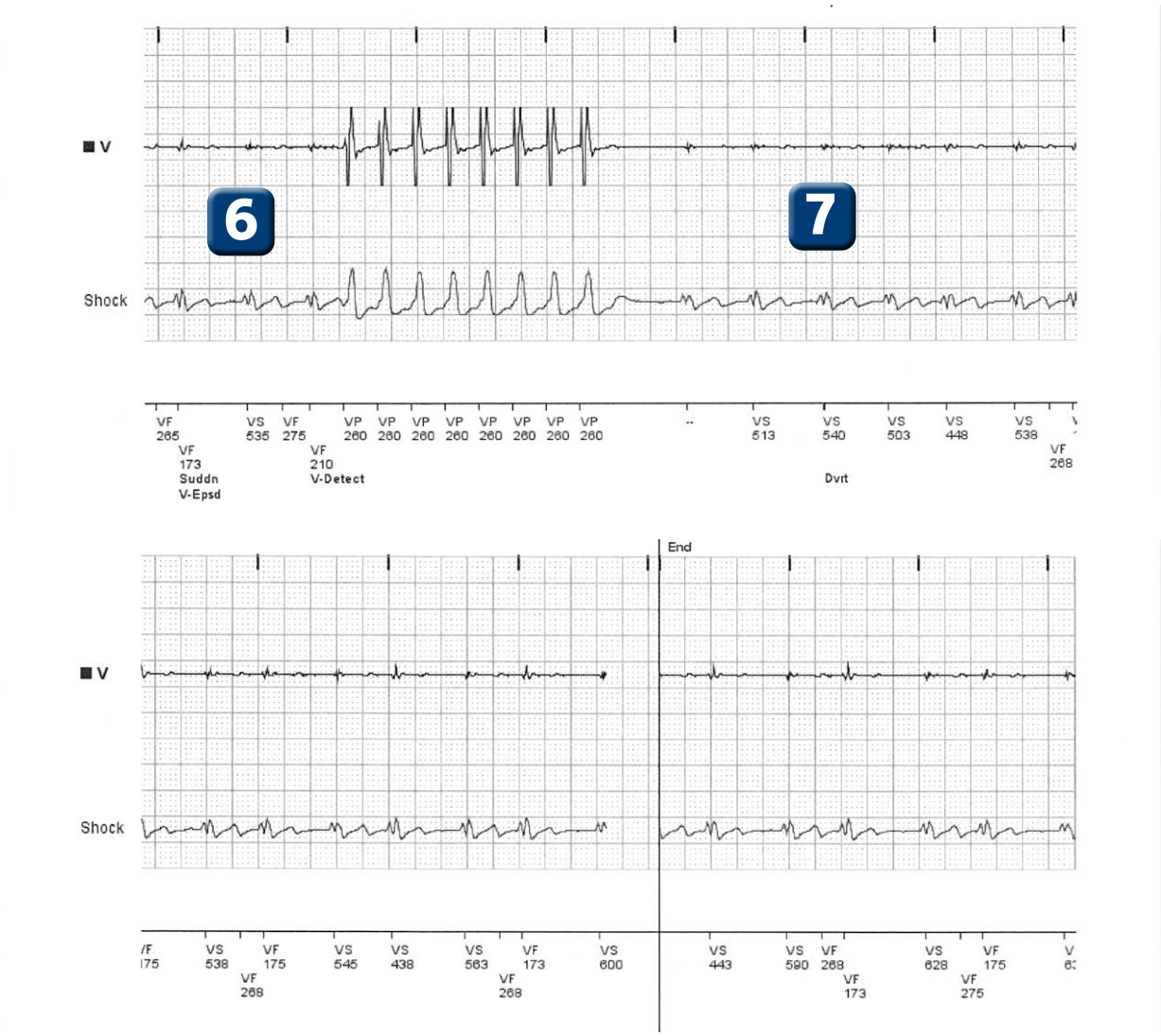
7 charge diversion in the absence of oversensing




V
Shock
3
4
VF 268 VF 265 VF 265 VS 473 VF 208 VS 475 VF 263 VS 473 VF 210 VS 475 VF 265 VS 473 VF 178 VP 855
3 VF 208 VF 208 V-Detect VF 210 Chrg VF 265 VF 213 VF 265 VF 210 VF 265


V
Shock
5
VP 855 VS 680 -- VS 495 VF 268 VF 215 VS 488 VS 483 VF 175 VF 260 VF 255 VS 478 VS 485 VS 483 VF 178 VS 513
Chrg
Dvrt
VF 270
VF 265


Attempt 1
V
Shock
VS 443 VS 518 VF 170 VS 528 VF 173 VS 538 VS 480 VS 510 VS 490 VF 265 VF 263 VF 270 VF 268 VS 530
VF 268
VF 263
VF 230
V-Epsd
VF 228
VF 225
VF 183

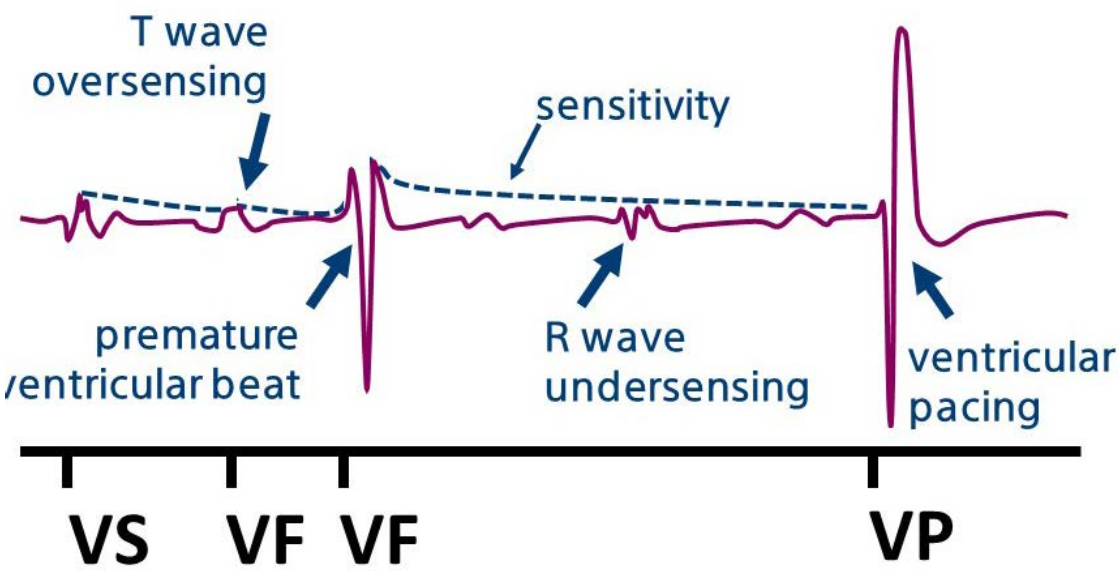


Points to remember

- although T wave oversensing remains a significant problem in the management of patients implanted with a defibrillator, this type of oversensing, which is fairly frequent with some brands, is very rare with Boston ScientificTM devices; in fact, the majority of clinicians managing this type of defibrillator have never observed it.
- T wave oversensing is associated with a typical alternation between 2 morphologically different signals, a high-frequency signal (R wave) and a low-frequency signal (T wave); for each cardiac cycle, the device counts the R wave and then the T wave as a second additional signal, resulting in a doubling of the heart rate; the alternating cycle length (RT intervals and TR intervals) is generally marked

for slow heart rates (short RT intervals and long TR intervals) but is often less marked during exercise (RT and TR intervals approximately equivalent) or for patients with a long QT

- T wave oversensing is more likely if the preceding R wave is of small amplitude (as in this patient); in fact, when the R wave is of small amplitude, the device rapidly reaches high levels of sensitivity, favoring T wave oversensing, particularly during exercise (which may result in a reduced R wave amplitude and a slight increase in the T wave amplitude); there are few reprogramming options in this context (no possibility of modifying filters, or reprogramming the adaptation level or delay, or margin to adjust the ventricular sensitivity); these situations are therefore difficult and any programming change compromises another aspect of programming; it may therefore be necessary to reposition the lead.



This figure shows T wave oversensing following a small amplitude R wave and then the occurrence of an extrasystole with under-sensing of the R wave which follows.

9 Oversensing of diaphragmatic myopotentials

Patient

- male implanted with an Incepta single-chamber defibrillator

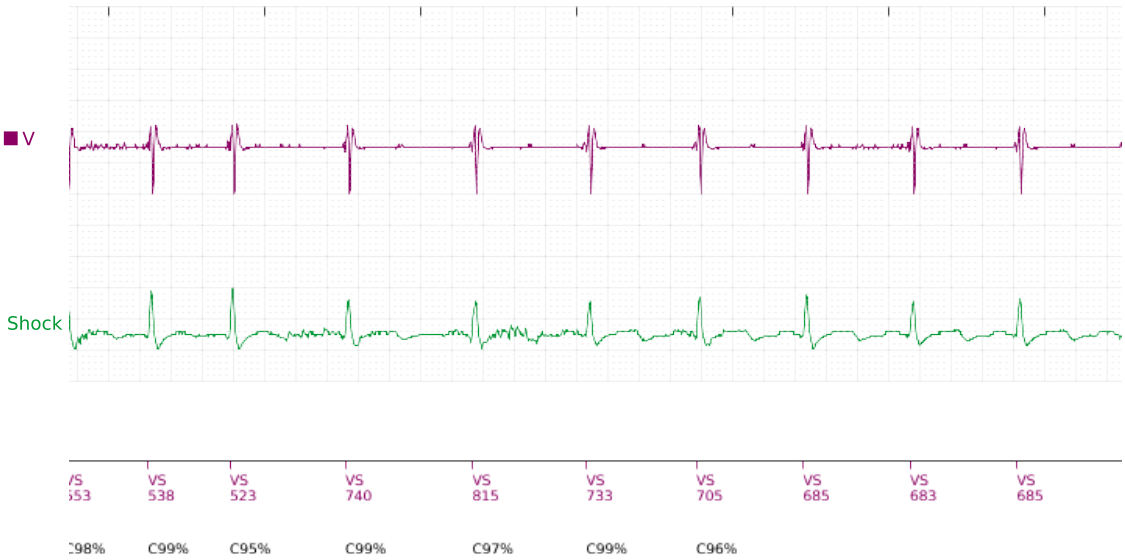
Summary

- detection of a non-sustained VT episode

EGM layout

1 the ventricular sensing channel intermittently senses non-physiological signals of relatively low amplitude (increasing then decreasing amplitude)

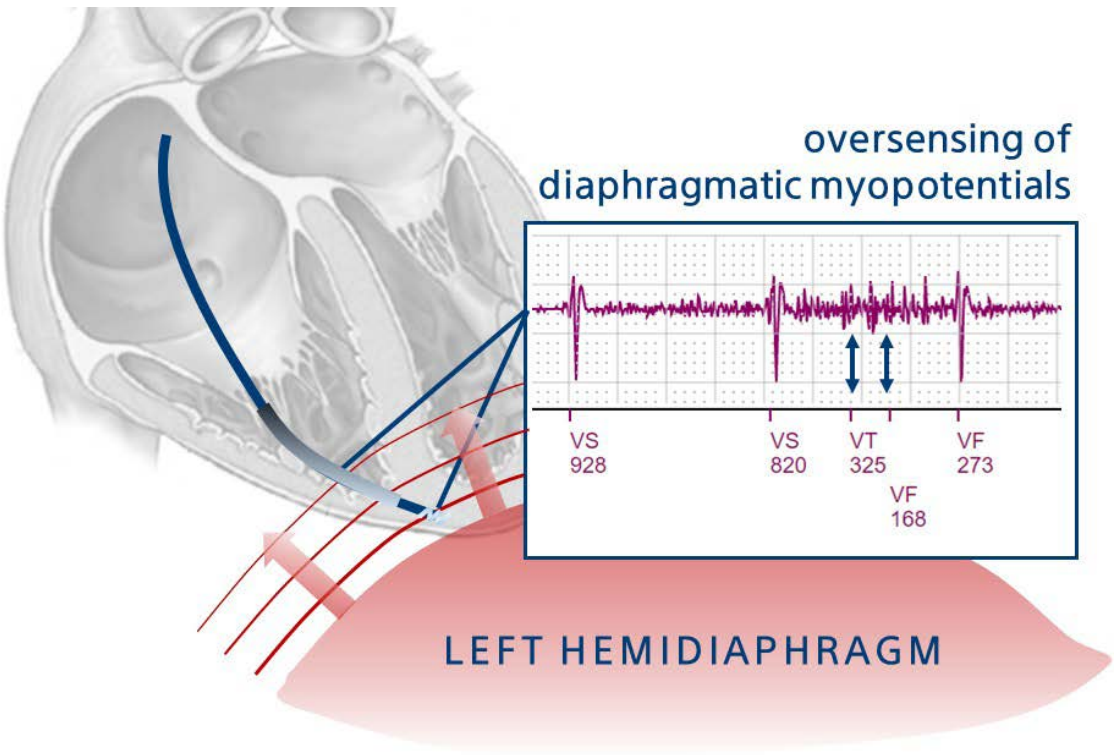
2 EGM trace recorded after 3 consecutive cycles classified as VF



Points to remember

- using a high auto-adaptive sensitivity optimizes the sensing of very low voltage signals during VF but increases the risk of oversensing diaphragmatic myopotentials at the end of diastole when the sensitivity is at its maximum
- oversensing of diaphragmatic myopotentials is rare but has been observed to a greater extent in patients implanted with an integrated bipolar lead positioned at the apex of the right ventricle; an integrated bipolar lead may promote occurrence of this phenomenon because the detection antenna is wider; permanent ventricular pacing is associated with an increased risk of oversensing of these myopotentials because, after pacing, the period of maximum sensitivity is prolonged, particularly when the heart rate is slow
- diaphragmatic myopotentials correspond to low amplitude, high frequency signals,

most often detected exclusively on the sensing channel (absent on the shock channel); the 2 main characteristics of this type of signal are that their amplitude varies during the respiratory cycle and that they can be reproduced by specific maneuvers (deep inspiration, Valsalva, forced cough); oversensing initially occurs at the end of diastole when sensitivity is at a maximum; detection of the true R wave (large amplitude) modifies the sensitivity level and at least temporarily interrupts oversensing of these small signals which explains why prolonged oversensing only occurs in pacing dependent patients (absence of spontaneous R wave, sensitivity level permanently at a maximum).



This figure shows the characteristic appearance of oversensing of diaphragmatic myopotentials: rapid signals of increasing and decreasing amplitude, detected on the sensing channel and absent on the shock channel.