Pr P. BORDACHAR

Dr K. MAHFOUZ

Dr S. PLOUX

Implantable Cardiac Pacemaker

Case studies based on **Abbott™** Tracings

Edition 2019

STIMUPRAT Editions

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STIMUPRAT Editions

liryc ELECTROPHYSIOLOGY AND HEART MODELING INSTITUTE BORDEAUX

Contributing authors :

P. Bordachar - CHU Haut Lévêque Bordeaux, Liryc
R. Eschalier - CHU Gabriel-Montpied Clermont-Ferrand
S. Garrigue - Clinique St Augustin Bordeaux
P. Plas - Stimuprat
S. Ploux - CHU Bordeaux, IHU Liryc
S. Reuter - Clinique St Augustin Bordeaux
P. Ritter - CHU Bordeaux, IHU Liryc
M. Strik - Maastricht University
P. Stiegler - Société Abbott™
A. Ximenes - Ch St Palais

Foreword

The authors of the Stimuprat team are pleased to present this book dedicated to the specificities of the interrogation and programming of the pacemakers marketed by Abbott™.

The galloping advances of the past 20 years have led to the development of highly complex devices capable of producing electrocardiographic tracings that are difficult to interpret if the physician does not possess a thorough knowledge of the functioning and specificities of each implanted prosthesis. Modern implantable devices, whether implantable loop recorders, cardiac pacemakers or implantable cardioverter defibrillators, store an increasing amount of diagnostic information relative to the operational functioning of the device.

This publication revisits the various phases of the interrogation and programming of the AbbottTM pacemakers through clinical cases, simple or more complex, depicting the different clinical situations encountered during the follow-up of an implanted patient. The reading of each tracing is didactically detailed, followed by a practical commentary proposing a solution to the illustrated problem with a reminder of good practices.

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

Pleasant reading !!!

CHAPTER 1

Pacing modes

SUMMARY

Patient

75-year-old man implanted with an Assurity™ + DR pacemaker for episodes of syncope due to paroxysmal atrioventricular block; well positioned leads with proper pacing and sensing thresholds; programming of various pacing modes and recording of the tracings.

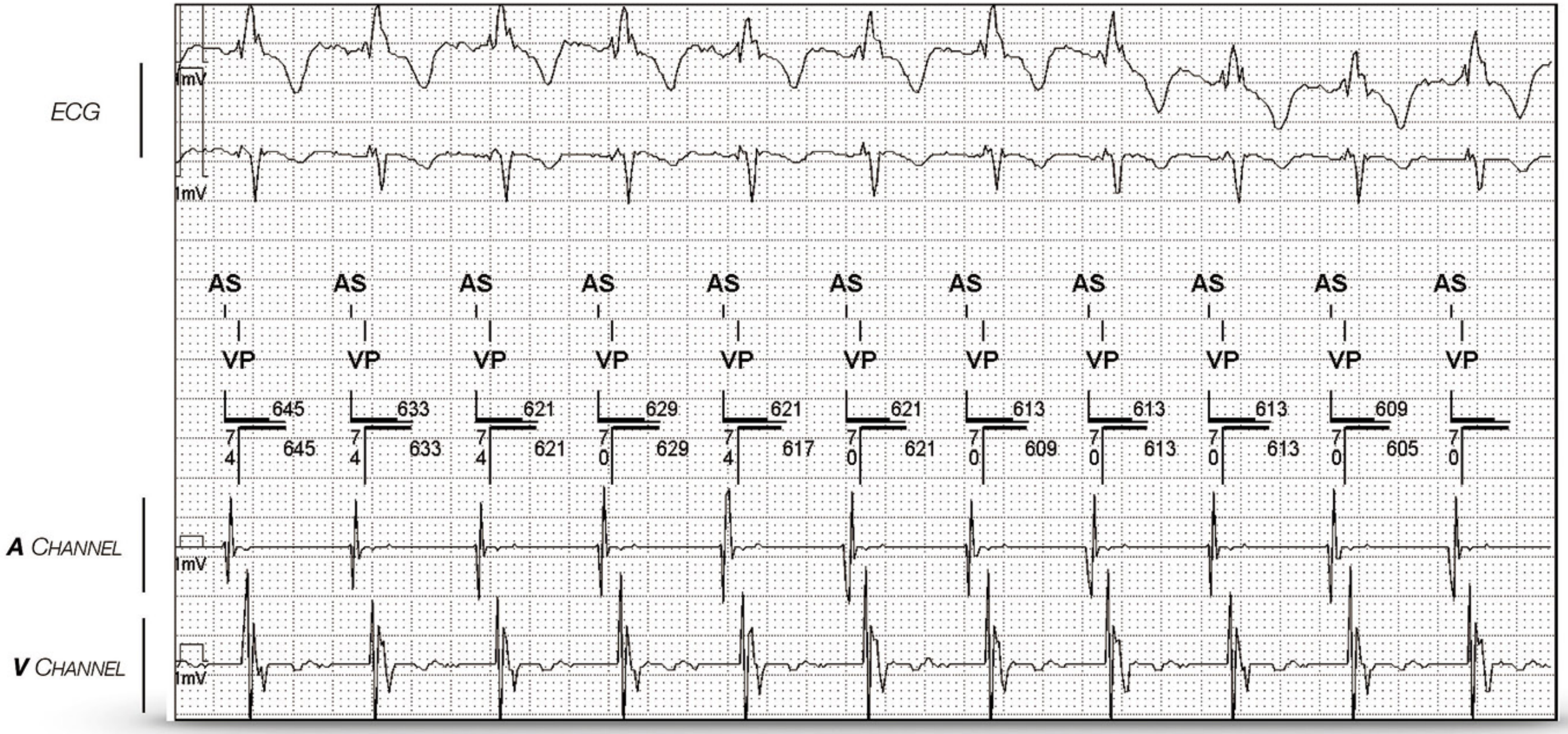
Quiz

Which pacing mode(s) is(are) compatible with this tracing?

A. VVI
B. VDD
C. DDI
D. VDI
E. DDD

ANSWER(S)

Pacing modes



AS Atrial sensing
VP Ventricular pacing

Tracing 1: VDD and DDD modes

SUMMARY

TRACING

Succession of AS-VP cycles (atrial sensing followed by ventricular pacing); this may therefore consist of a dual-chamber VDD or DDD mode that allows ventricular triggering (ventricular pacing) upon atrial sensing, which is impossible for VDI and DDI modes.

COMMENTS

The choice of pacing mode is the first essential step in programming a dual-chamber pacemaker since it directly affects the other remaining parameters to be programmed. Different pacing modes are programmable depending on the number of leads and the implanted device model. Pacing modes are defined by a 4-letter code describing their basic operation. The first letter defines the pacing chamber(s): ventricle (V), atrium (A), both (D) or none (O). The second letter defines the sensing chamber(s): same letters. The third letter indicates the mode of operation: inhibited (I), triggered (T), dual (D, I + T) or none (O). The fourth letter indicates whether there is rate modulation (rate response, R).

This tracing can correspond to the operation of VDD mode or DDD mode.

The VDD mode can be programmed on a dual-chamber pacemaker but can also be obtained from a single-chamber device with a single VDD lead bearing two floating atrial electrodes providing atrial sensing and two ventricular pacing/sensing electrodes. Sensing is carried out in both the atrium and the ventricle whereas pacing is only carried out in the ventricle; any atrial pacing is thus impossible. When the atrial rate is greater than the programmed minimum rate, the ventricle is paced synchronously up to the maximum synchronous rate. When the atrial rate is below the programmed minimum rate, the pacemaker operates in a pseudo-VVI mode. This mode is therefore acceptable in the absence of sinus dysfunction, and it is preferable to program a low minimum rate, possibly with rate hysteresis in order to preserve atrioventricular synchrony.

The advantages of single-lead VDD systems are:

1) only one lead is needed therefore enabling a sometimes shorter implantation procedure as well as a reduced amount of endovascular material;

2) the absence of trauma to the atrial wall allows preventing the development of atrial fibrosis;

3) in patients without sinus dysfunction, the physiological atrioventricular activation sequence is ensured.

The drawbacks of single-lead VDD systems are:

1) that atrial sensing is sometimes less accurate than with a separate atrial lead, since the atrial dipole may move away from the chamber wall, especially during deep breathing and heart movements;

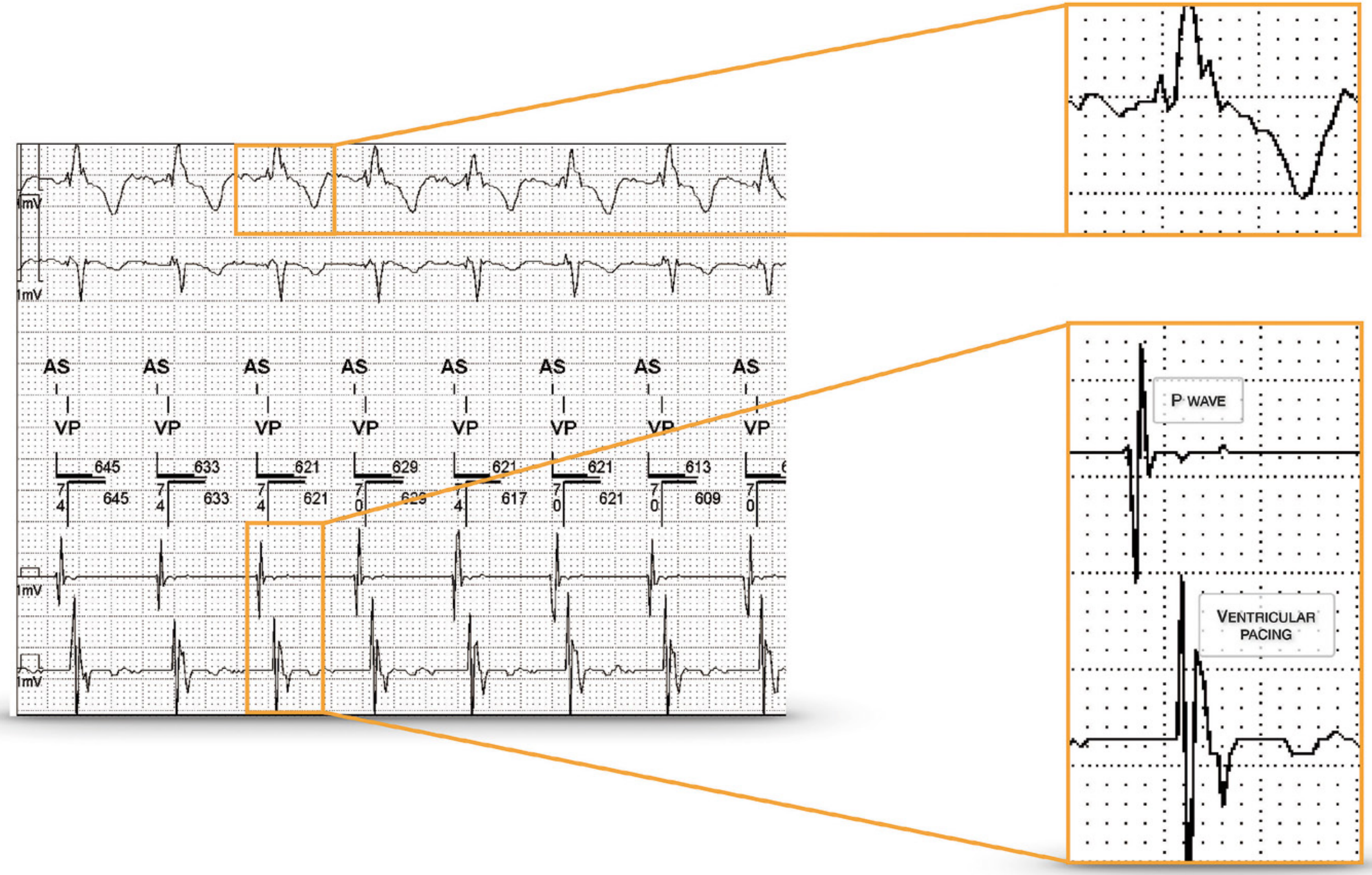
2) the detection of atrial arrhythmias is sometimes less accurate for the same reasons, rendering memory data less reliable;

3) in case of loss of paroxysmal atrial sensing during exertion and presence of atrioventricular block, the pacing rate returns to the base rate with possible sudden drop in rate, possible pacemaker syndrome and risk of pacemaker-mediated tachycardia;

4) this mode should be avoided in the presence of sinus dysfunction. The preferential indication of the VDD mode is therefore complete atrioventricular block with normal sinus function.

The basic principle of the DDD mode is to synchronize ventricular pacing on both atrial sensing and pacing. Any atrial sensing outside the refractory period and any atrial pacing results in ventricular pacing at the end of the AV delay in the absence of intrinsic ventricular sensing. This mode therefore preserves atrioventricular synchrony for low sinus rates and up to high rates (maximum rate limit).

The VDD mode may be indicated in implanted patients in the setting of a complete atrioventricular block with preserved sinus function. The DDD mode allows fulfilling the characteristics presented by all implanted patients although can be associated with a high percentage of right ventricular pacing in patients with preserved atrioventricular conduction.


1mV
AS
VP
645
633
621
629
613
617
609
P WAVE
VENTRICULAR PACING

VDD/DDD MODE

Patient

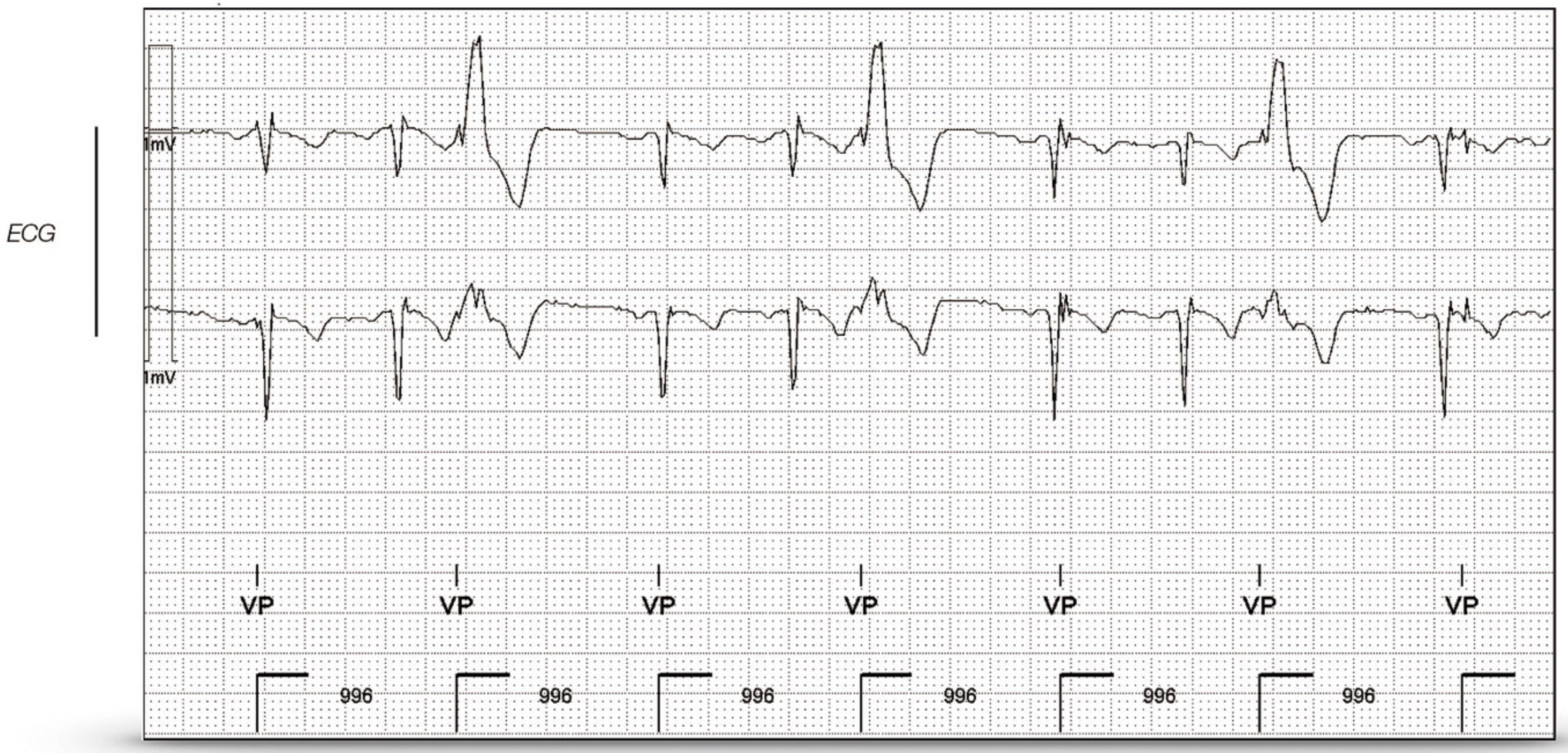
Same patient as in tracing 1; change of pacing mode (the leads function correctly).

Quiz

Which mode is compatible with this tracing?

A. VVI 60 beats/minute
B. VDD 60 beats/minute
C. VOO 60 beats/minute
D. ODO
E. VVT 60 beats/minute

ANSWER(S)



VP Ventricular pacing

Tracing 2: asynchronous AOO, VOO and DOO modes

TRACING

Programming in VOO mode 60 beats/minute; fixed-rate asynchronous ventricular pacing without sensing of intrinsic atrial or ventricular events; there is no capture after ventricular pacing when it occurs immediately after intrinsic ventricular activity (refractory period of the ventricular myocardium); on the other hand, effective ventricular capture when the pacing occurs remotely from the intrinsic QRS, with pacing occurring at the peak of the T wave (proarrhythmic risk).

COMMENTS

Fixed-rate asynchronous modes were the only available modes on the initial first-generation pacemakers. The VOO mode induces sequential asynchronous ventricular pacing, without inhibition by intrinsic events. As seen on this tracing, when the patient is not pacemaker-dependent, parasystole occurs with competition between intrinsic activity and paced activity. This mode allows verifying pacing effectiveness and avoiding inhibition in the event of exposure to external interference (electric scalpel in a pacemaker-dependent patient for example). Pacing is effective and captures ventricular activity only when it occurs outside the physiological absolute ventricular refractory period following an intrinsic ventricular event.

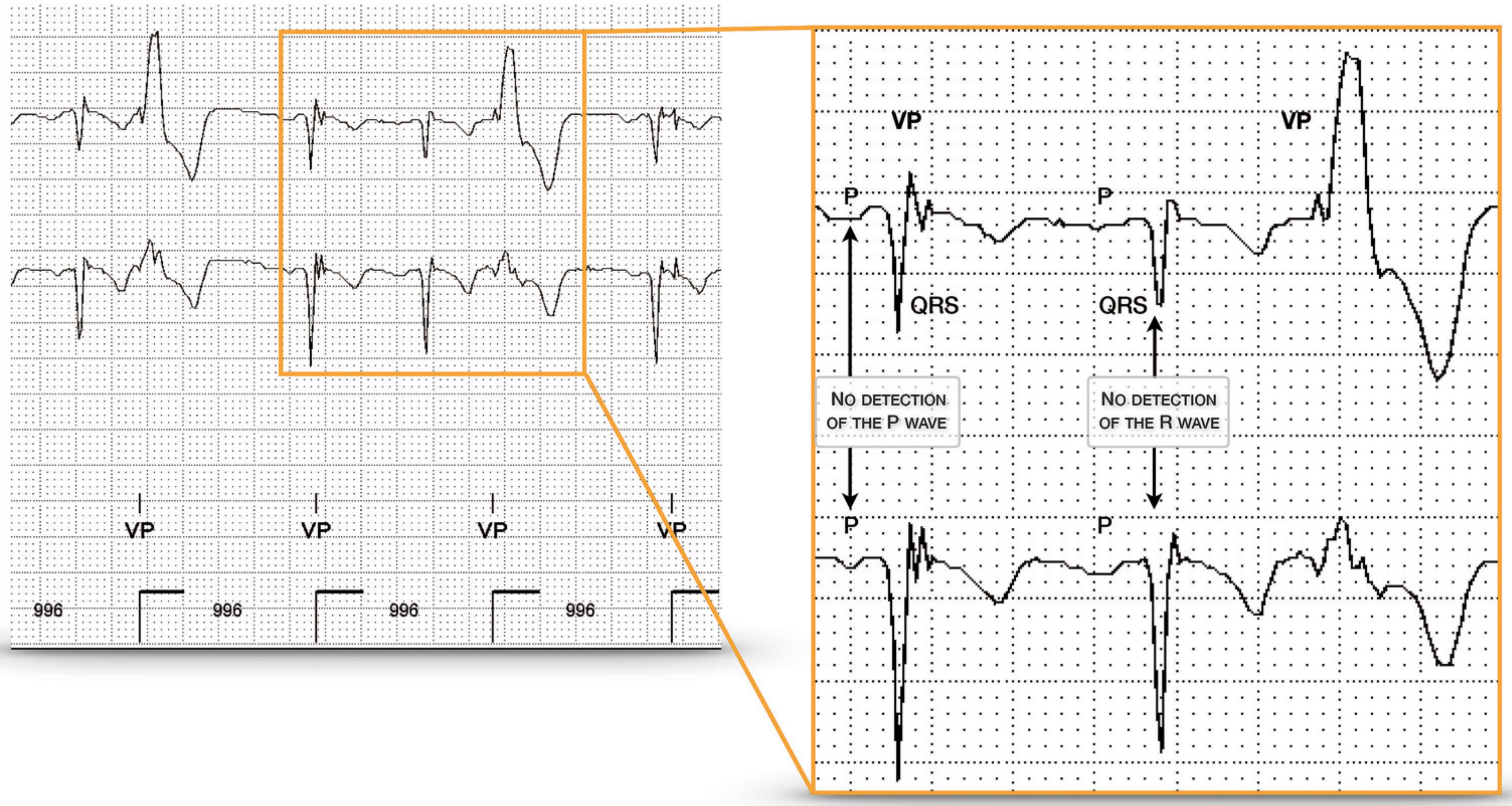
This tracing illustrates the risk associated with this type of mode. Several ventricular pacing pulses occur at the peak of the T wave of an unsensed intrinsic QRS. This is the vulnerable period with risk of induction of a ventricular rhythm disorder. The risk of ventricular fibrillation is limited, although increases in the presence of myocardial ischemia or metabolic disorders. Similarly for AOO or DOO modes, asynchronous atrial pacing in the vulnerable atrial period can induce atrial fibrillation.

Asynchronous modes are nowadays obsolete and are only used in 2 specific circumstances:

1) magnetic or magnet mode; indeed, the application of a magnet causes AOO, VOO or DOO pacing according to the programmed mode;

2) the asynchronous modes can be programmed temporarily for device-dependent patients with an MRI-compatible pacemaker scheduled to undergo an MRI exam.

Asynchronous modes allow fixed rate pacing without inhibition by intrinsic activation of the patient. There is nonetheless a risk of pacing during a potentially-arrhythmogenic atrial or ventricular vulnerable period.



VOO mode 60 bpm

Patient

Same patient as in tracing 1; change of pacing mode (the leads function normally).

Quiz

Which mode is compatible with this tracing?

A. VVI 60 beats/minute

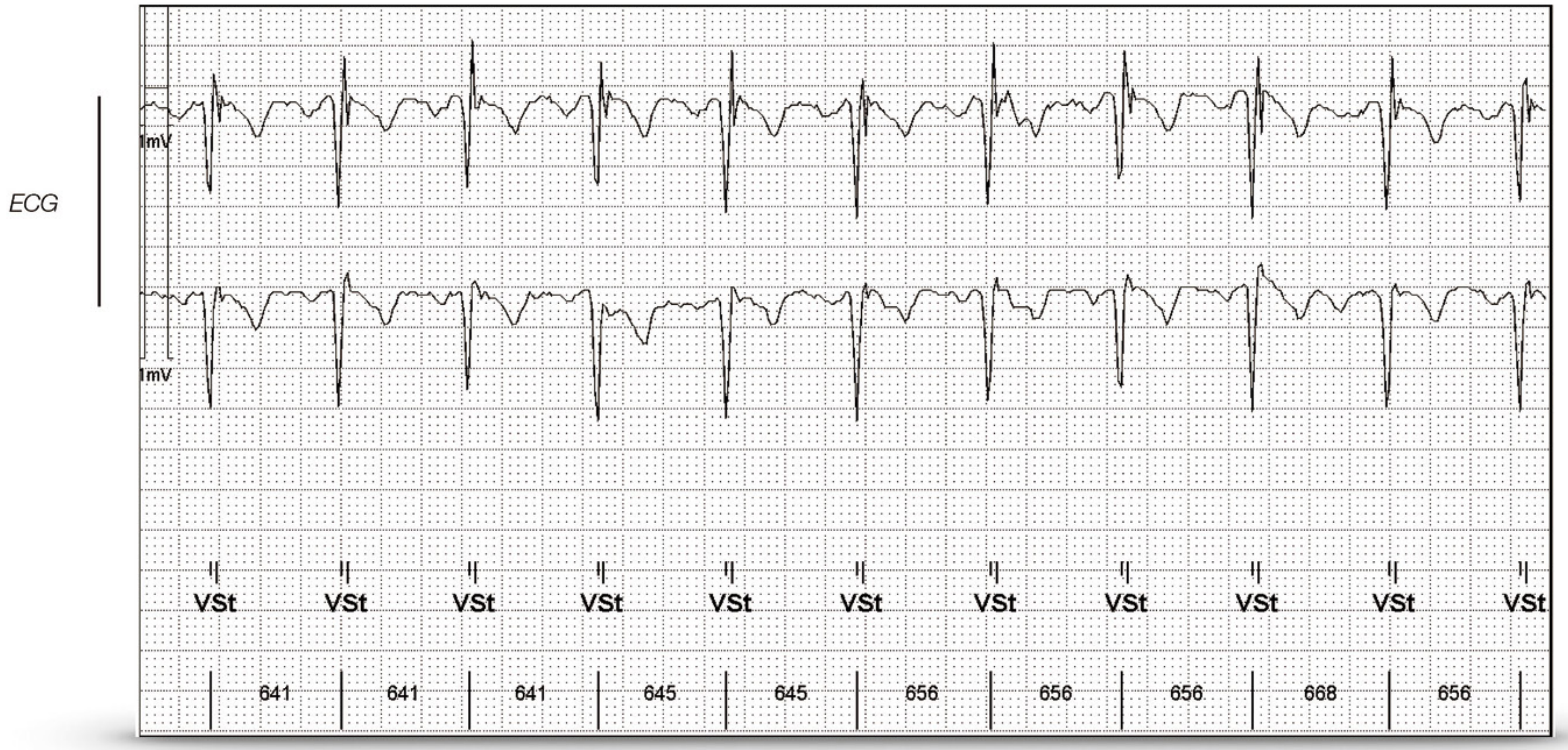
B. VDD 60 beats/minute

C. VOO 60 beats/minute

D. ODO

E. VVT 60 beats/minute

ANSWER(S)



VSt Triggered ventricular pacing

Tracing 3: triggered AAT, VVT, DDT modes

TRACING

Programming in VVT mode 60 beats/minute; each ventricular sensing (VS) triggers a ventricular pacing (t for trigger); the pattern of the intrinsic QRS does not appear to be modified by the ventricular pacing which occurs during the myocardial refractory period.

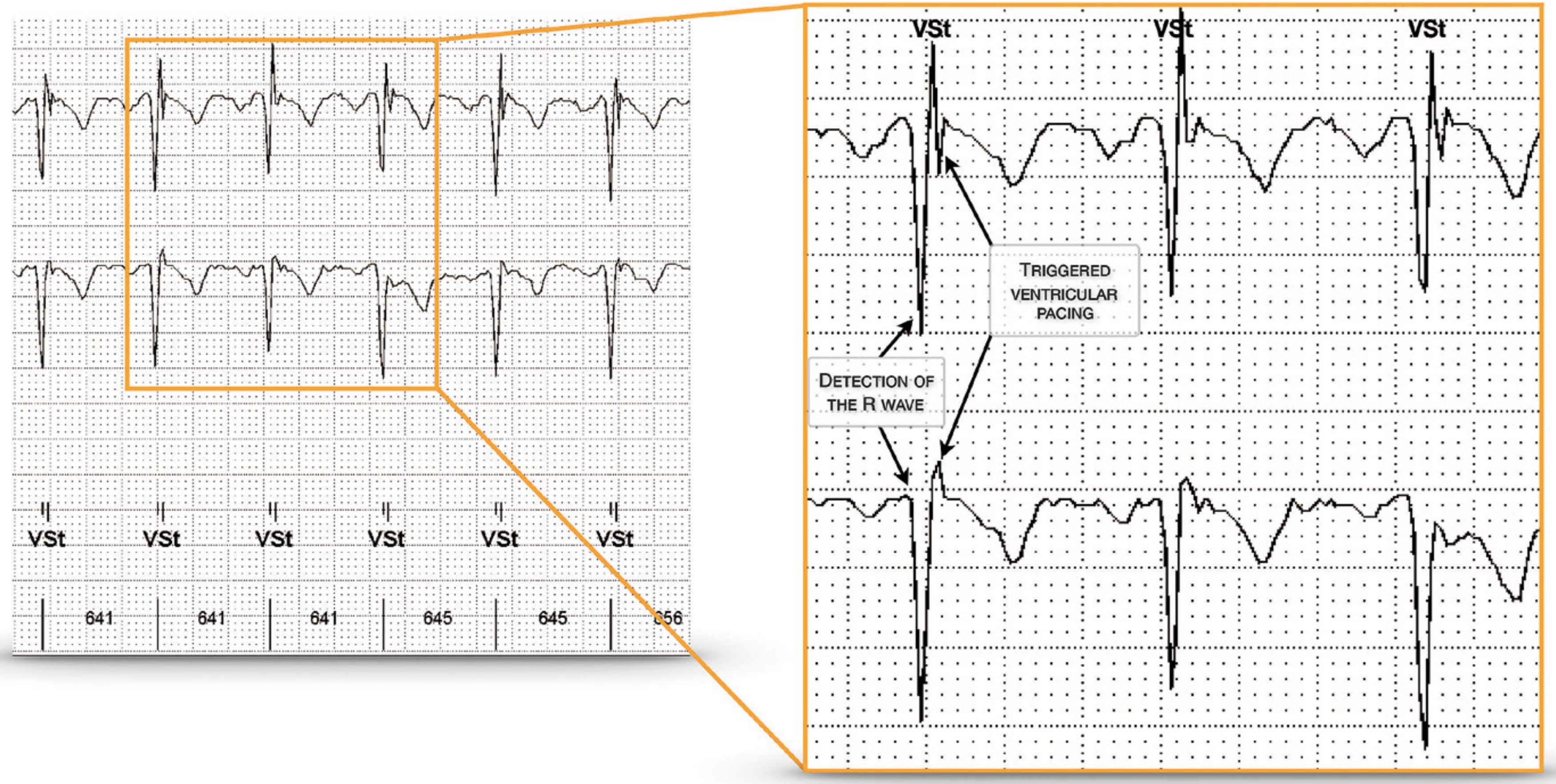
COMMENTS

When the VVT mode is programmed, the sensing of a ventricular complex triggers an immediate pacing in the absolute refractory period of the ventricular myocardium (trigger). If no ventricular activity is sensed, pacing occurs at the programmed minimum rate. This operation therefore corresponds to the opposite of the VVI mode where sensing inhibits pacing. This type of pacing mode is currently rarely programmed in the long term since associated with an unnecessary increase in energy consumption. The triggered modes can be used in 2 particular circumstances:

1) in the event of sensing of myopotentials or of electromagnetic interference, a pacemaker programmed in SST mode does not inhibit but induces pacing on each artifact sensed outside the refractory period, which allows avoiding a pause in pacemaker-dependent patients. This type of pacing mode was of particular interest in older pacemaker models which were more susceptible to external interferences since they only functioned in unipolar mode.

2) this mode allows assessing the quality of sensing in the considered chamber as well as verifying the absence of far-field oversensing and that extrasystoles are also properly sensed.

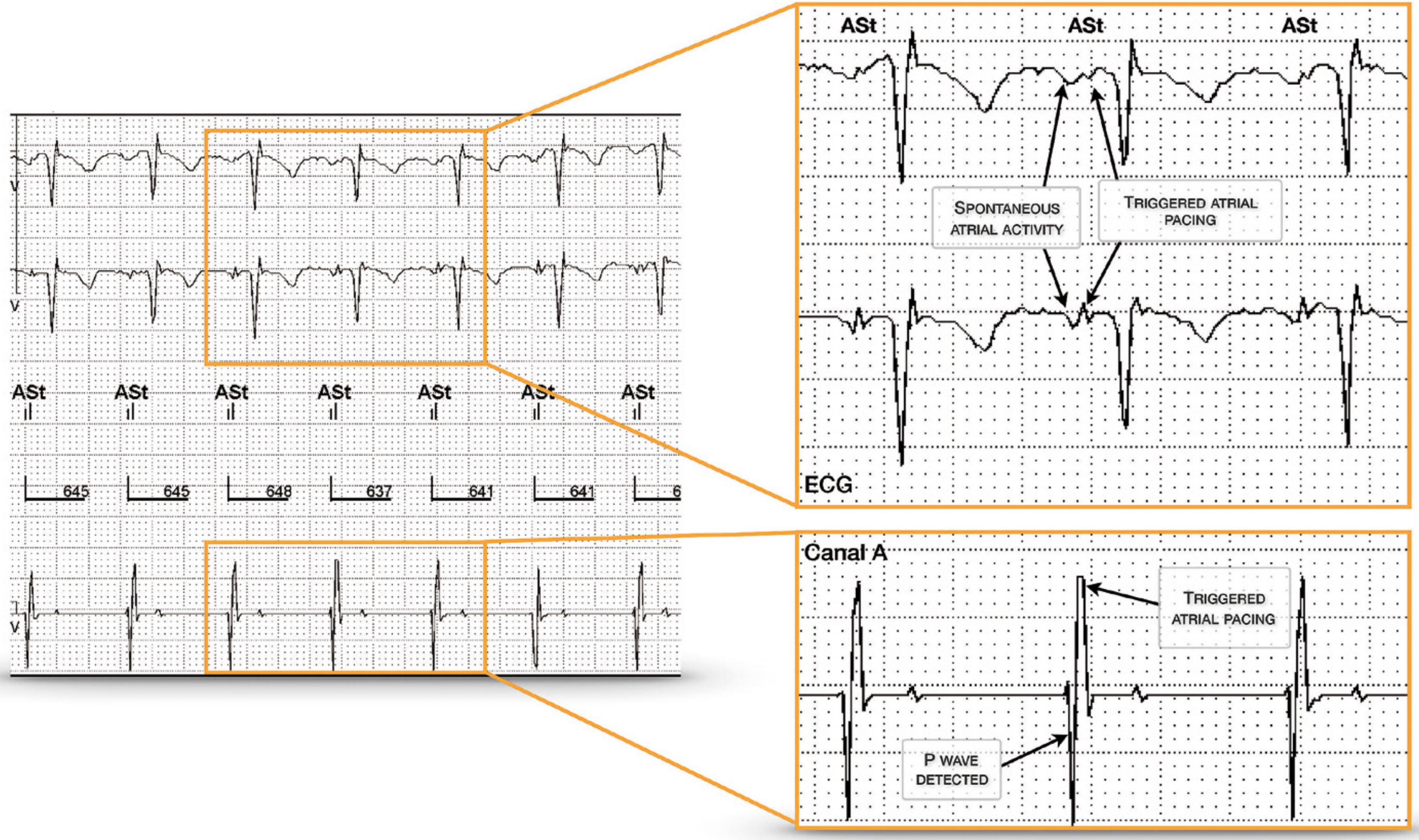
Triggered modes (AAT, VVT) are associated with an unnecessary increase in consumption contributing to battery wear and are therefore rarely programmed in the long term when the pacemaker is operating normally. However, they can be useful in pacemaker-dependent patients presenting a pacing inhibition as a result of oversensing of myopotentials or of electromagnetic interference.



VVT MODE 60 BPM

TRACING

Programming in AAT mode 60 beats/minute; each atrial sensing (AS) triggers an atrial pacing (t for trigger).



AAT mode 60 bpm

SUMMARY

Patient

Same patient as in tracing 1; change of pacing mode (the leads function normally).

Quiz

Which mode is compatible with this tracing?

A. AAI 60 beats/minute

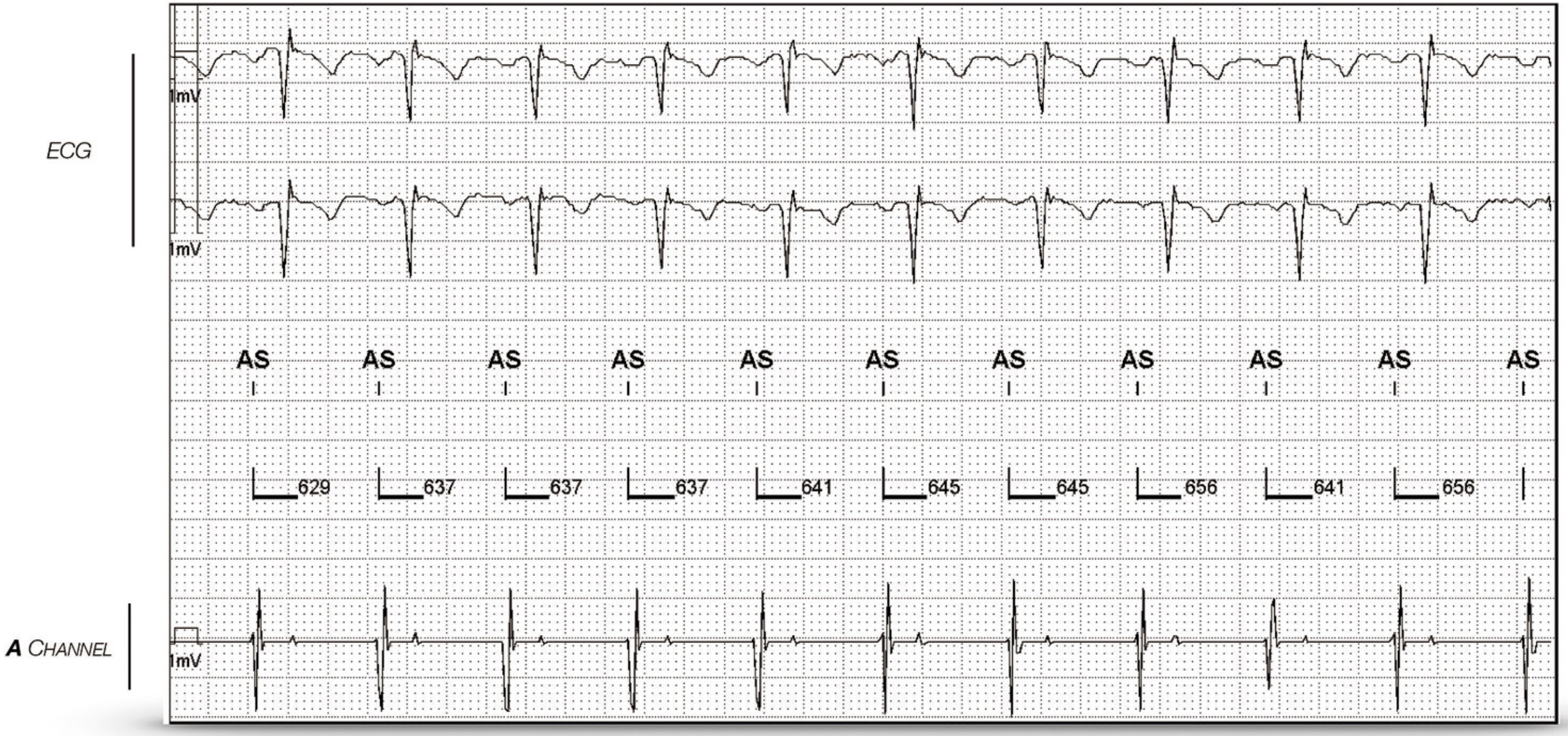
B. AAT 60 beats/minute

C. AOO 60 beats/minute

D. ODO

E. VDD 60 beats/minute

ANSWER(S)



AS Atrial sensing

Tracing 5: single-chamber AAI mode

TRACING

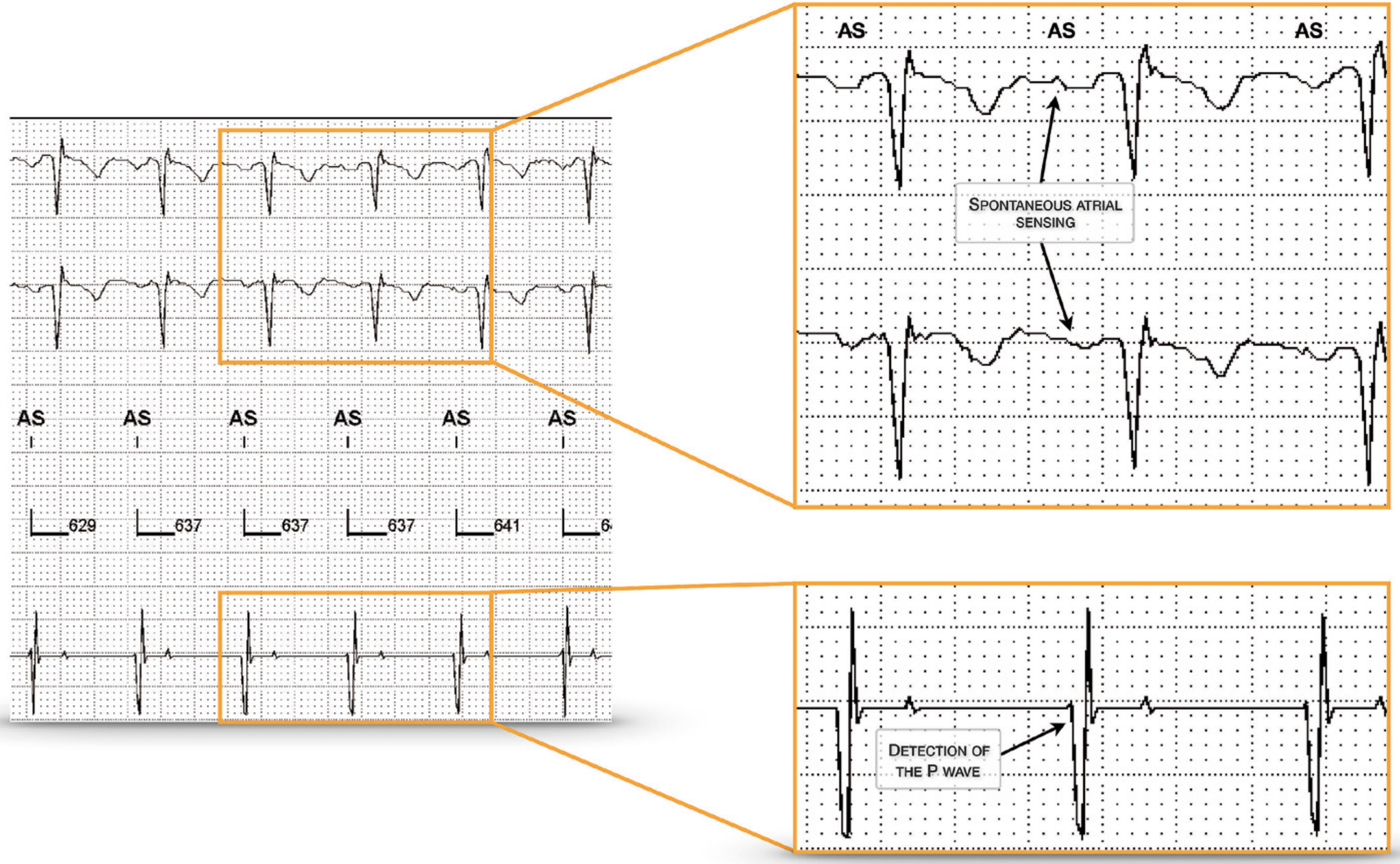
Programming in AAI mode 60 beats/minute; sensing of a stable atrial activity with inhibition of pacing (it is therefore not an AAT or AOO mode); absence of sensing of QRS complexes (it is therefore not an ODO or VDD mode).

COMMENTS

A single-chamber pacemaker operates in AAI mode when only one lead is positioned in the atrium; the AAI mode can also be programmed in a dual-chamber pacemaker. The AAI mode provides single-chamber atrial pacing at the programmed pacing rate unless inhibited by a sensed event. Sensing only applies to the atrium.

Single-chamber AAI pacemakers or AAI mode programming on a dual-chamber pacemaker are formally contraindicated in patients with a permanent or paroxysmal atrioventricular conduction disorder. They should also be avoided in patients with vagal symptoms or carotid sinus syndrome. The preferred indication is therefore pure sinus dysfunction without atrioventricular conduction disorder. An AAI pacemaker allows limiting the number of implanted leads, ensures a physiological rate at rest and during exercise after programming of the rate response and avoids any unnecessary ventricular pacing. A recent study, however, reported unfavorable results for the implantation of a single-chamber AAI pacemaker compared to the implantation of a dual-chamber pacemaker in patients with sinus dysfunction. Indeed, the rate of re-intervention was higher in patients implanted with an AAI pacemaker with the need to add a ventricular lead secondarily to the occurrence of an atrioventricular conduction disorder. More surprisingly, the incidence of atrial fibrillation episodes was also higher. The indications for implantation of a single-chamber AAI pacemaker are thus nowadays relatively limited.

The programming and operation of the AAI mode are essentially similar to that of a VVI pacemaker. However, it is necessary to program a higher sensitivity (lower programmed value) since the amplitude of the atrial complexes are often lower than that of the ventricular complexes. Similarly, the refractory period must be longer to avoid oversensing of ventricular complexes. The sensing of the R wave by an AAI pacemaker leads to a decrease in pacing rate, with the R wave recycling the escape interval. In the presence of oversensing of the far-field R wave, it is possible to render the pacemaker less sensitive and/or to prolong the refractory period.



AAI mode 60 bpm

Patient

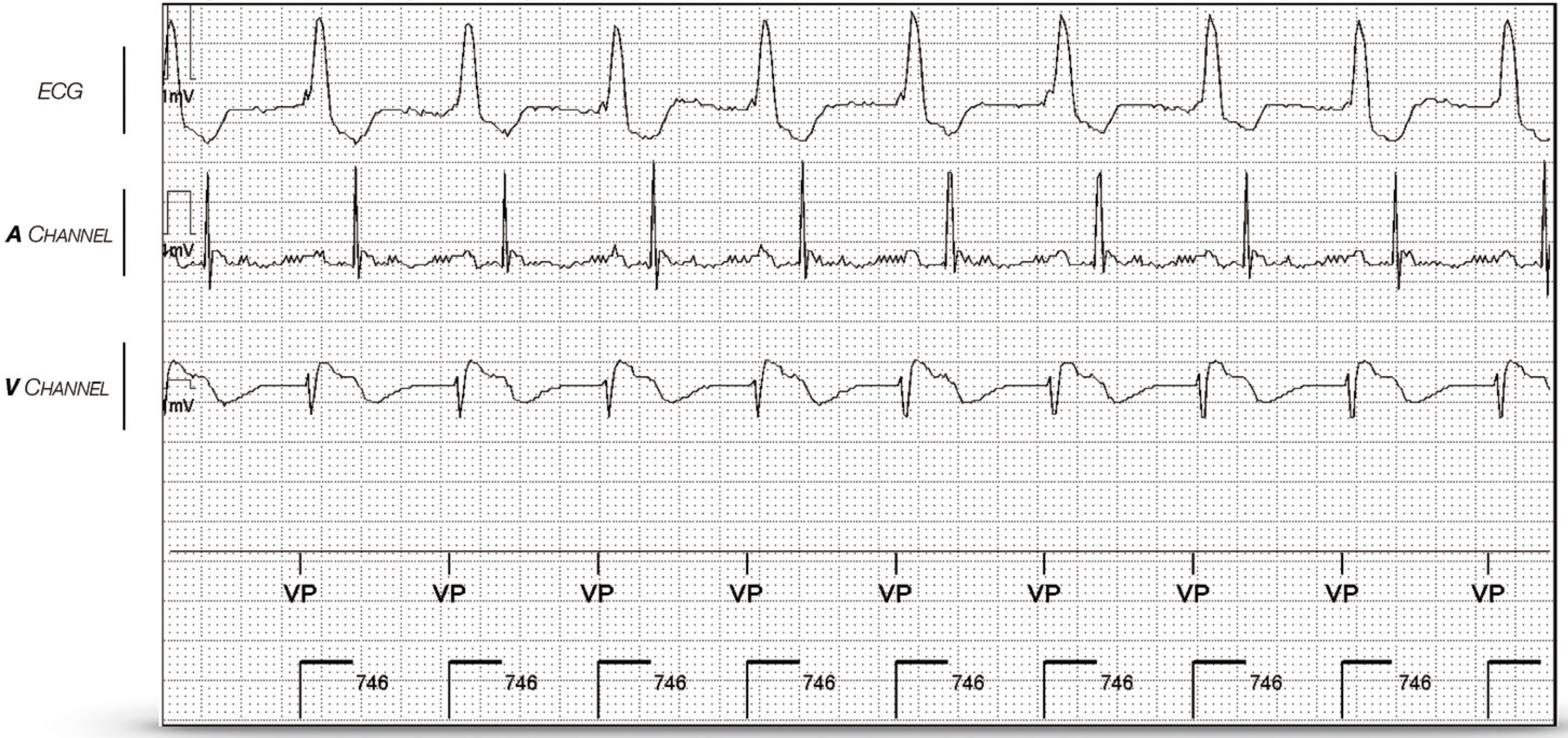
81-year-old man implanted with an Assurity MRI™ pacemaker for symptomatic episodes of paroxysmal atrioventricular block.

Quiz

Which mode is compatible with this tracing?

A. VVI 60 beats/minute
B. VOO 60 beats/minute
C. VVT 60 beats/minute
D. VVI 80 beats/minute
E. VDD 80 beats/minute

ANSWER(S)



VP Ventricular pacing

Tracing 6: single-chamber VVI mode

TRACING

Programming in VVI mode 80 beats/minute; fixed pacing at 80 beats/minute with no sensing of atrial activity; the 3 possible modes are therefore VVI, VVT or VOO 80 beats/minute; the 1:1 atrial activity follows ventricular pacing; probable retrograde atrial activation.

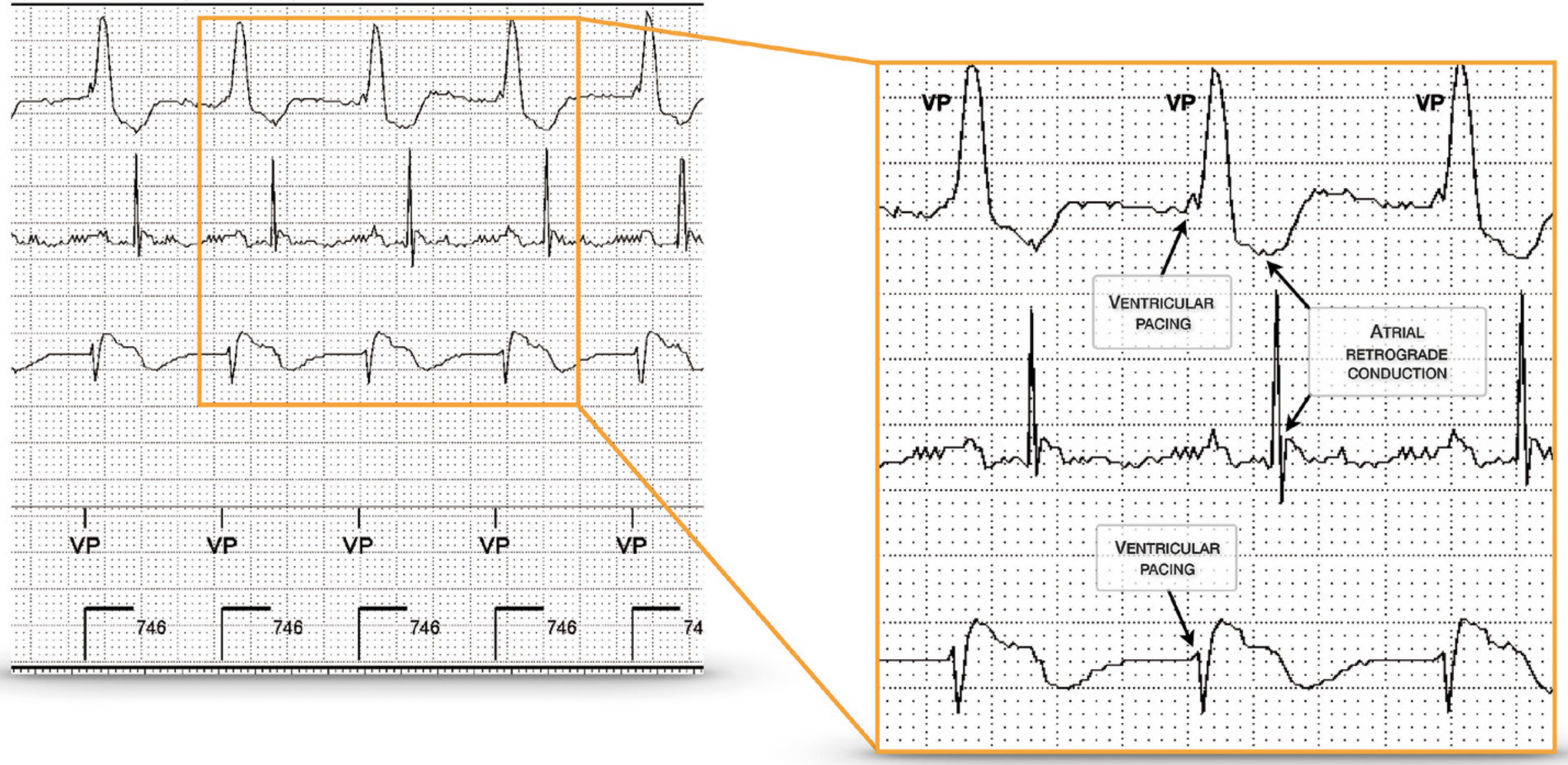
COMMENTS

A single-chamber pacemaker operates in VVI mode when only one lead is positioned in the ventricle; the VVI mode can also be programmed in a dual-chamber pacemaker. The VVI mode provides single-chamber ventricular pacing at the programmed pacing rate, unless inhibited by a sensed ventricular event. Sensing only applies to the ventricle.

For this patient, programming of the base rate is essential. Indeed, at 80 beats/minute, the base rate is too high and there is permanent ventricular pacing with inversion of the physiological atrioventricular activation sequence. EGMs show a 1:1 retrograde atrial conduction. Atrial contraction occurs while the atrioventricular valves are closed causing a retrograde flow to the atria, pulmonary veins and vena cava. Pacemaker syndrome results from a complex combination of hemodynamic, neurohumoral and vascular alterations. A sometimes very disabling symptomatology, due to the increase in atrial pressure and venous pressure, can include dyspnea, orthopnea, pulsations in the neck and chest, palpitations, or chest pain.

Conversely, at 50 beats/minute, the minimum rate is lower than the intrinsic rate and the patient is not paced. This sentinel mode allows avoiding unnecessary pacing in non-pacemaker-dependent patients, thereby reducing consumption while avoiding the occurrence of retrograde conduction.

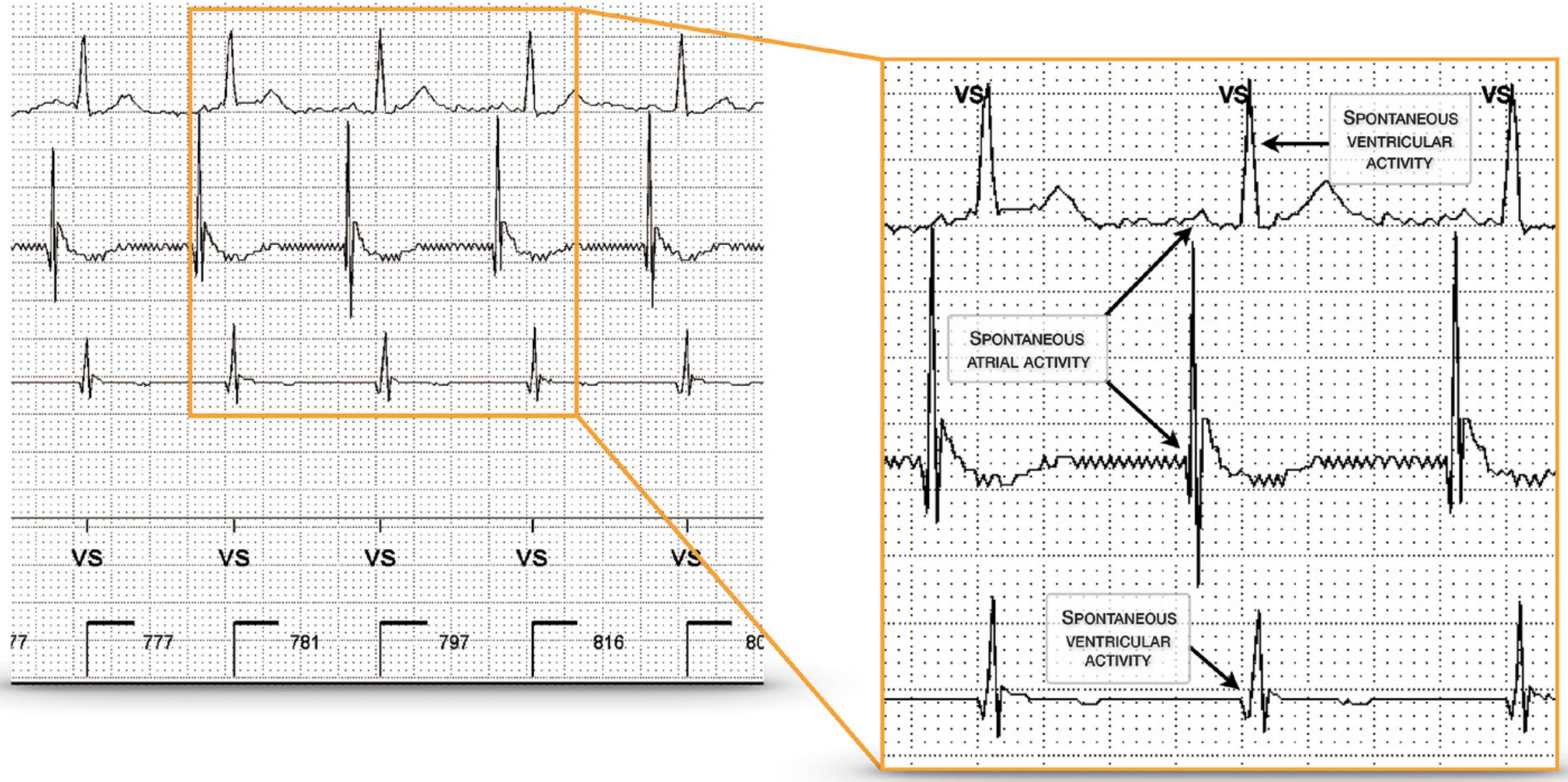
Pacemaker syndrome corresponds to the presence of repeated sequences of ventricular pacing - retrograde atrial conduction; atrial contraction occurs when the mitral valves are closed, which can lead to disabling symptoms.



VVI mode 80 bpm

TRACING

Same patient with VVI programming in VVI mode 50 beats/minute; ventricular sensing (VS) and inhibition of ventricular pacing.



VVI 50 BPM MODE

Patient

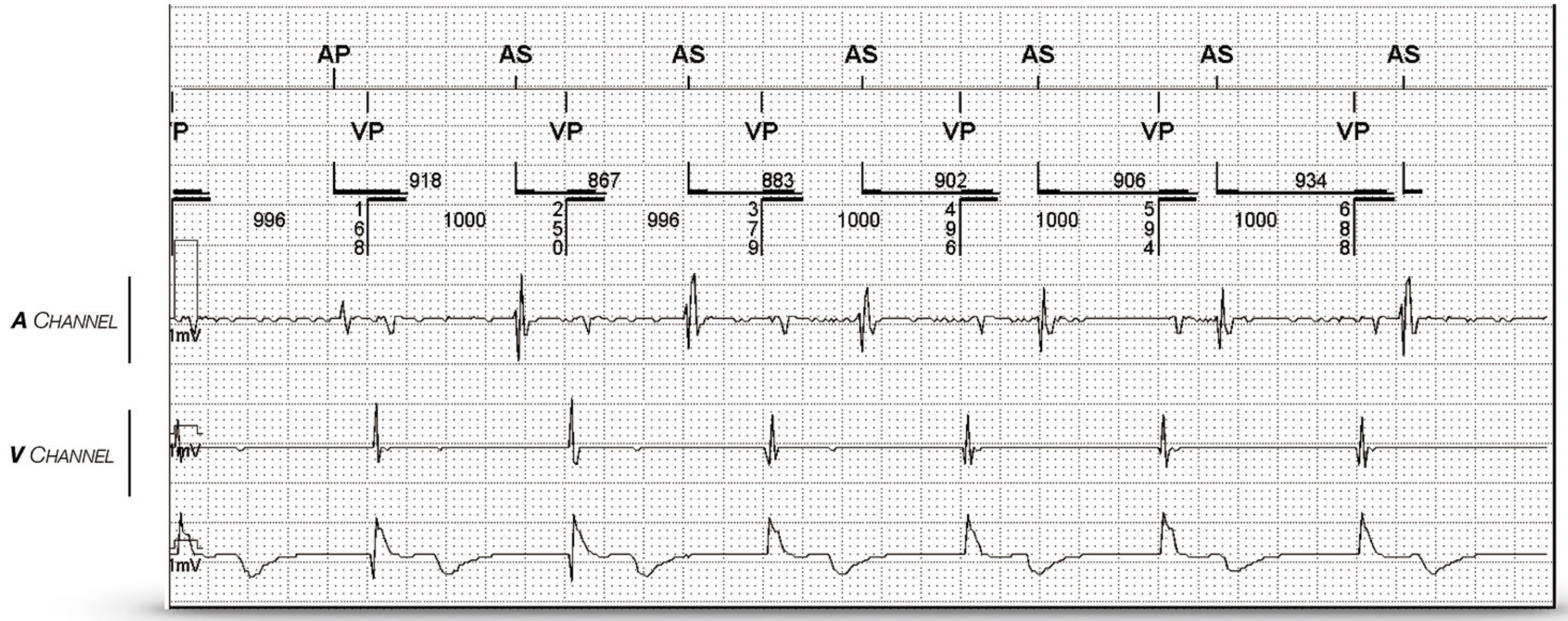
81-year-old man implanted with an Accent MRI™ pacemaker for complete atrioventricular block.

Quiz

Which mode is compatible with this tracing?

A. VVI
B. VOO
C. VDD
D. DDD
E. DDI

ANSWER(S)



AS Atrial sensing
VP Ventricular pacing

Tracing 8: dual-chamber DDI mode

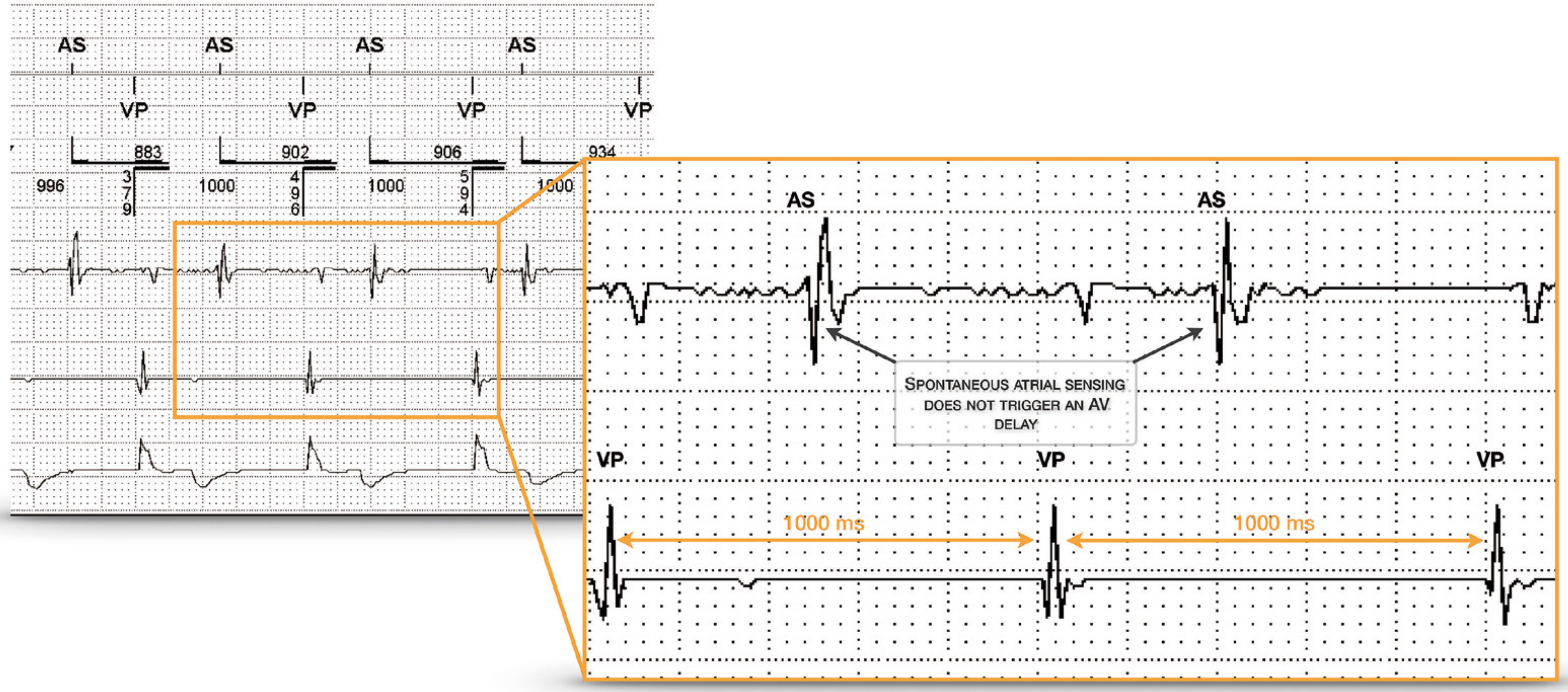
TRACING

Programming in DDI mode 60 beats/minute; fixed ventricular pacing at 60 beats/minute; sensing of regular atrial activity disassociated from ventricular pacing; the sensed atrial activity does not trigger an AV delay (characteristic feature of the DDI mode which does not allow the trigger function).

COMMENTS

The DDI mode provides atrioventricular sequential pacing (AP-VP) but without ventricular triggering of the sensed atria. Atrioventricular synchrony is only provided at the current atrial pacing rate (base rate, rate response, or smoothed rate). If atrial activity is faster than the atrial pacing rate as on the first tracing, atrial pacing is inhibited and there is no triggering of AV delay (operation equivalent to the VVI mode). This allows avoiding runaway ventricular pacing upon occurrence of atrial arrhythmia and explains the use of DDI as fallback mode. This mode can also be programmed in the long term, when in DDD mode, the pacemaker does not properly detect an atrial arrhythmia leading to the absence of fallback and erratic ventricular pacing. The choice of DDI mode is not appropriate in a patient with complete atrioventricular block and normal sinus function (absence of P-synchronous pacing), although is conversely completely acceptable if the patient, even with complete atrioventricular block, also presents a sinus dysfunction triggering permanent atrial pacing. Setting the base rate is therefore essential. It must be sufficiently high to avoid the occurrence of intrinsic atrial activation and be associated with a rate response. In this patient, programming at 70 beats/minute ensured a satisfactory atrioventricular synchrony.

A patient with atrioventricular block and atrial disease associated with rapid AF episodes (no risk of runaway) and permanent sinus dysfunction after termination (synchronized AP-VP pacing) is the preferred indication of the DDI mode.

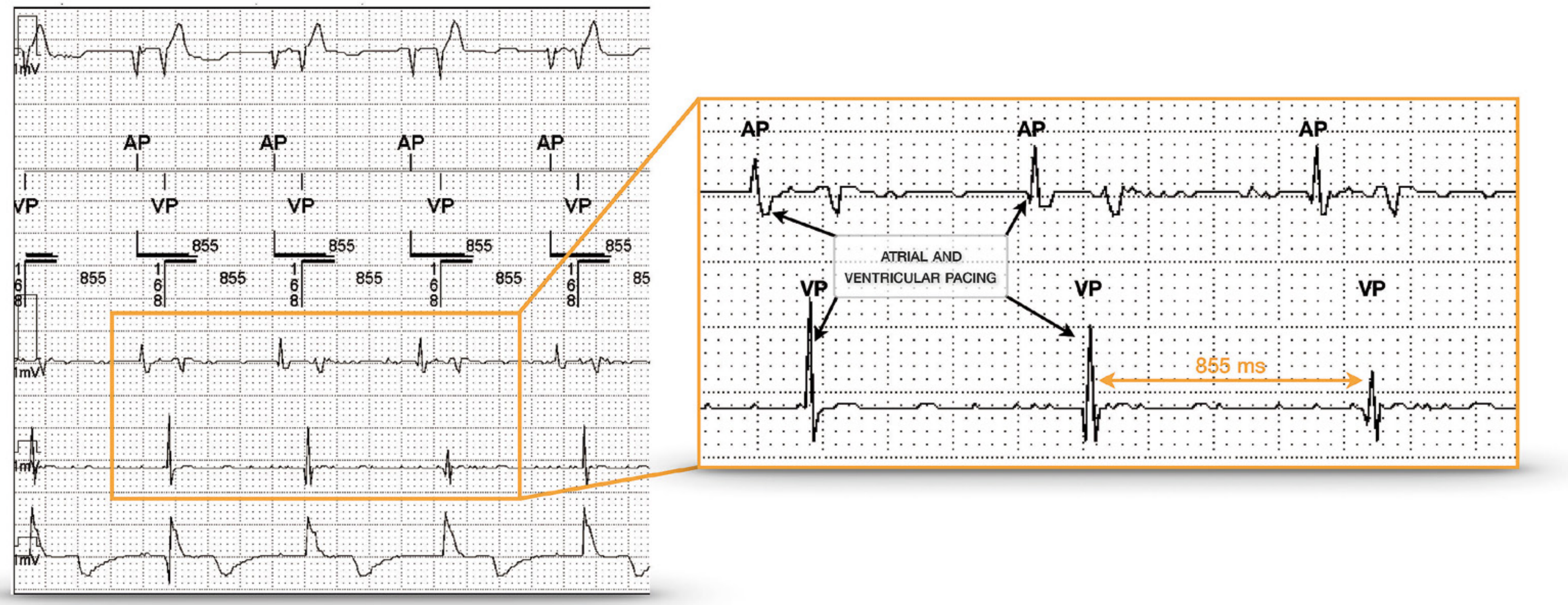


DDI mode 60 bpm

Tracing 9: dual-chamber DDI mode

TRACING

Same patient with programming in DDI mode 70 beats/minute; atrial and ventricular pacing at 70 beats/minute.



DDI MODE 70 BPM

Patient

74-year-old man implanted with an Accent™ DR pacemaker for sinus dysfunction; programming of the VIP algorithm.

Quiz

Which answer(s) is(are) true regarding the VIP algorithm?

A. the VIP algorithm corresponds to an ADI-DDD operating mode

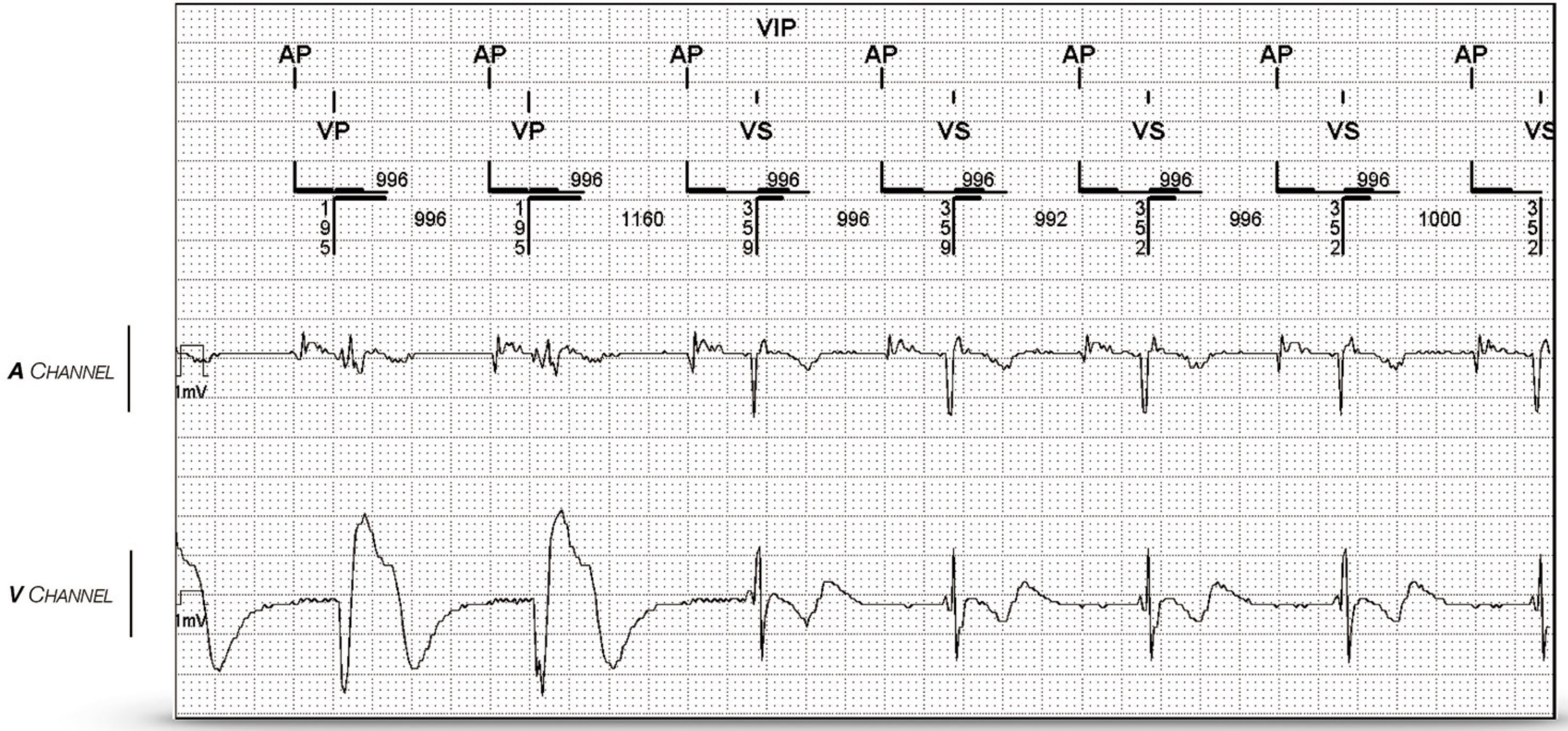
B. the VIP algorithm corresponds to an AV delay hysteresis

C. during the search phase of intrinsic conduction, the VIP algorithm tolerates the presence of a blocked P wave

D. During the search phase of intrinsic conduction, the VIP algorithm does not tolerate a blocked P wave

E. During the search phase of intrinsic conduction, the VIP algorithm allow an AV delay until 400 ms

ANSWER(S)



AP Atrial pacing
VP Ventricular pacing

Tracing 10: pacing in DDD-VIP mode

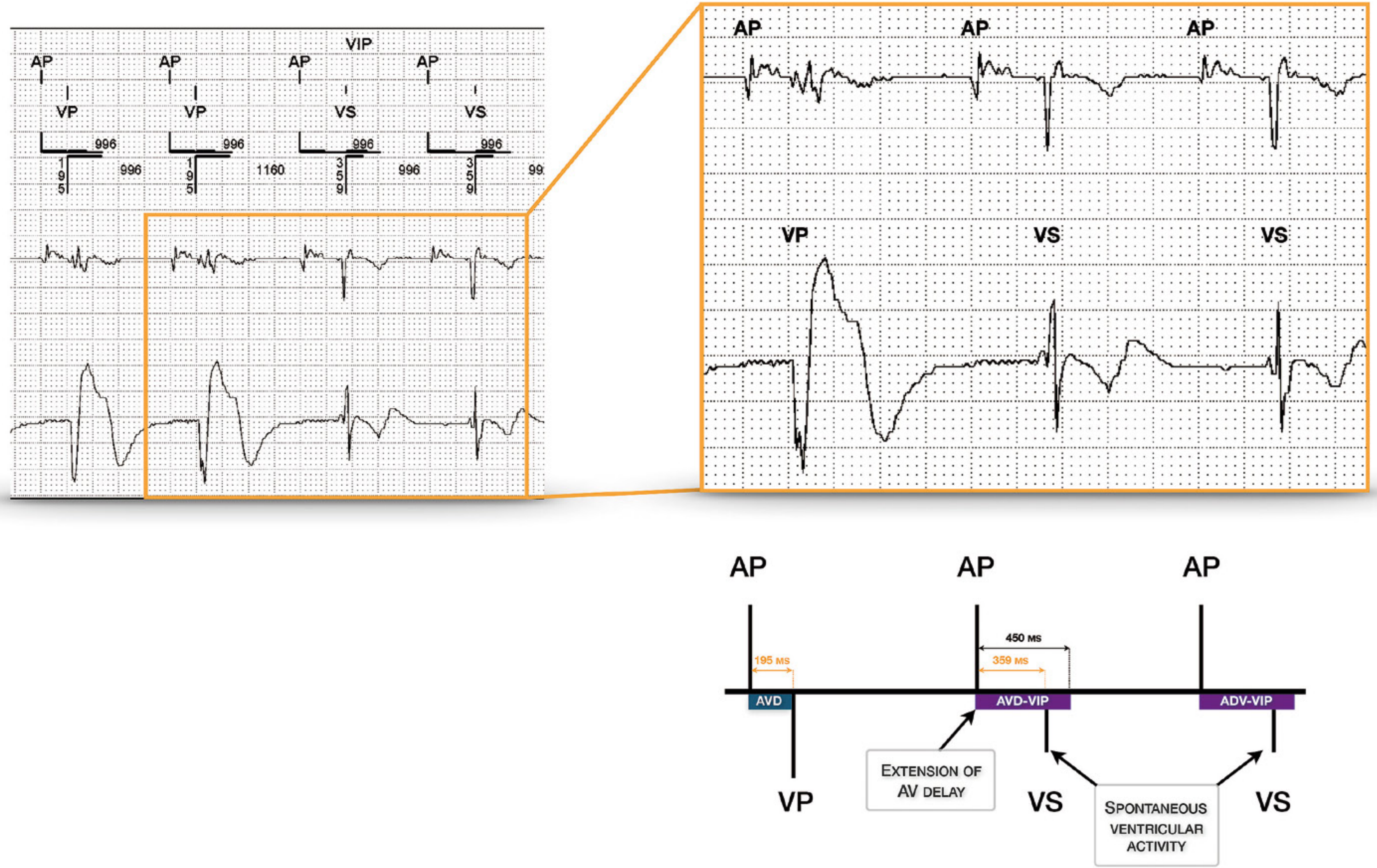
TRACING

Initially, atrial pacing and ventricular pacing at the minimum rate; intervention of the VIP algorithm with AV delay hysteresis; resumption of intrinsic conduction and inhibition of ventricular pacing.

COMMENTS

There is extensive literature demonstrating the deleterious effect of prolonged right ventricular pacing. One of the priorities of programming is therefore to minimize any unnecessary ventricular pacing. Different modes or algorithms have been proposed by the manufacturers to reduce the percentage of ventricular pacing without compromising the safety of the patient upon occurrence of an atrioventricular conduction disorder. There is no such specific mode per se for Abbott™ pacemakers. The VIP algorithm corresponds to an AV delay hysteresis. The AV delay is prolonged over a limited number of intervals to promote the return of intrinsic conduction. At the end of the prolonged AV period, if no ventricular event has occurred, ventricular pacing is delivered. On this tracing, the major advantage of this algorithm appears obvious. Indeed, compared to the beginning of the tracing, activation of the VIP allows reducing the percentage of pacing from 100 to 0%. In the long term, this should prove beneficial in terms of ventricular remodeling and occurrence of atrial arrhythmia. Analysis of the percentage of ventricular pacing is therefore an important follow-up element in a patient implanted for sinus dysfunction; it is indeed essential to attempt to minimize the occurrence of any unnecessary pacing. Note that on this tracing, the AP-VS interval is relatively prolonged (around 360 ms on paced atrial activity) although remains shorter than the programmed maximum AV delay during the search (450 ms in this patient).

The VIP corresponds to an AV delay hysteresis with prolongation of the AV delay over 1 to 3 intervals in order to promote the return of intrinsic conduction.


VIP
AP
VP
VS
996
1160
195
359
AP
VP
VS
AP
AP
AP
195 ms
450 ms
359 ms
AVD
AVD-VIP
ADV-VIP
VP
VS
VS
Extension of AV delay
Spontaneous ventricular activity

DDD-VIP mode

Patient

74-year-old man implanted with an Accent™ DR pacemaker for paroxysmal atrioventricular block; programming of the VIP algorithm.

Quiz

Which answer(s) is(are) true regarding the VIP algorithm?

A. the search interval corresponding to the time interval between each intrinsic conduction search is programmable between 30 seconds and 30 minutes

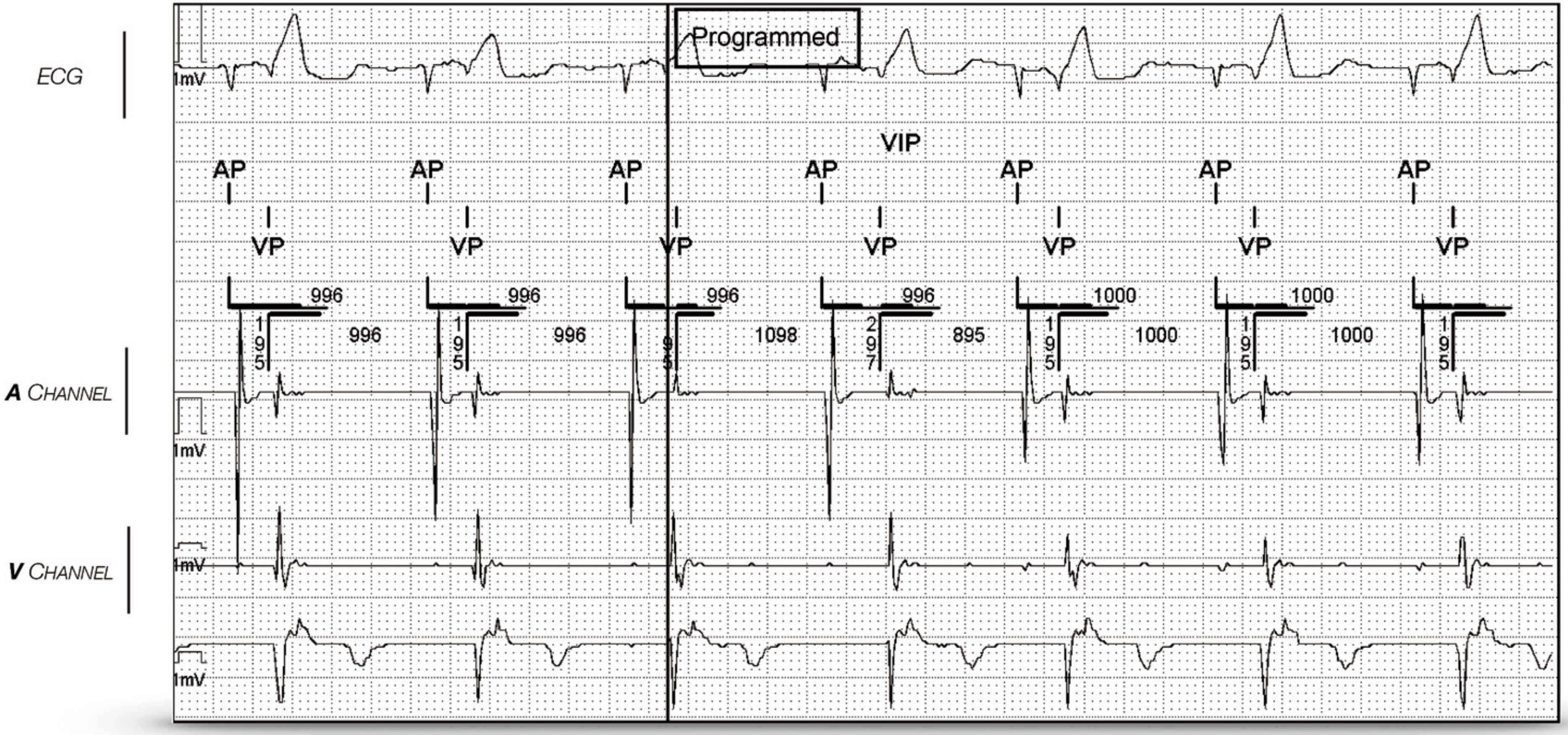
B. the search interval corresponding to the time interval between each intrinsic conduction search is programmable between 10 seconds and 10 minutes

C. the number of consecutive cycles with prolonged AV delay during which the search for intrinsic conduction occurs is programmable between 1 and 3

D. the number of consecutive cycles with prolonged AV delay during which the search for intrinsic conduction occurs is programmable between 1 and 5

E. the maximum duration of the AV delay during which the search for intrinsic conduction occurs is 450 ms

ANSWER(S)



AP Atrial pacing
VP Ventricular pacing

Tracing 11: pacing in DDD-VIP mode

SUMMARY

TRACING

Atrial and ventricular pacing (AV delay of 195 ms); programming of the VIP algorithm; prolongation of the AV delay by 100 ms (programmable) for 1 cycle only (programmable); absence of intrinsic ventricular activity and ventricular pacing; unsuccessful search and return to DDD mode at the programmed AV delay.

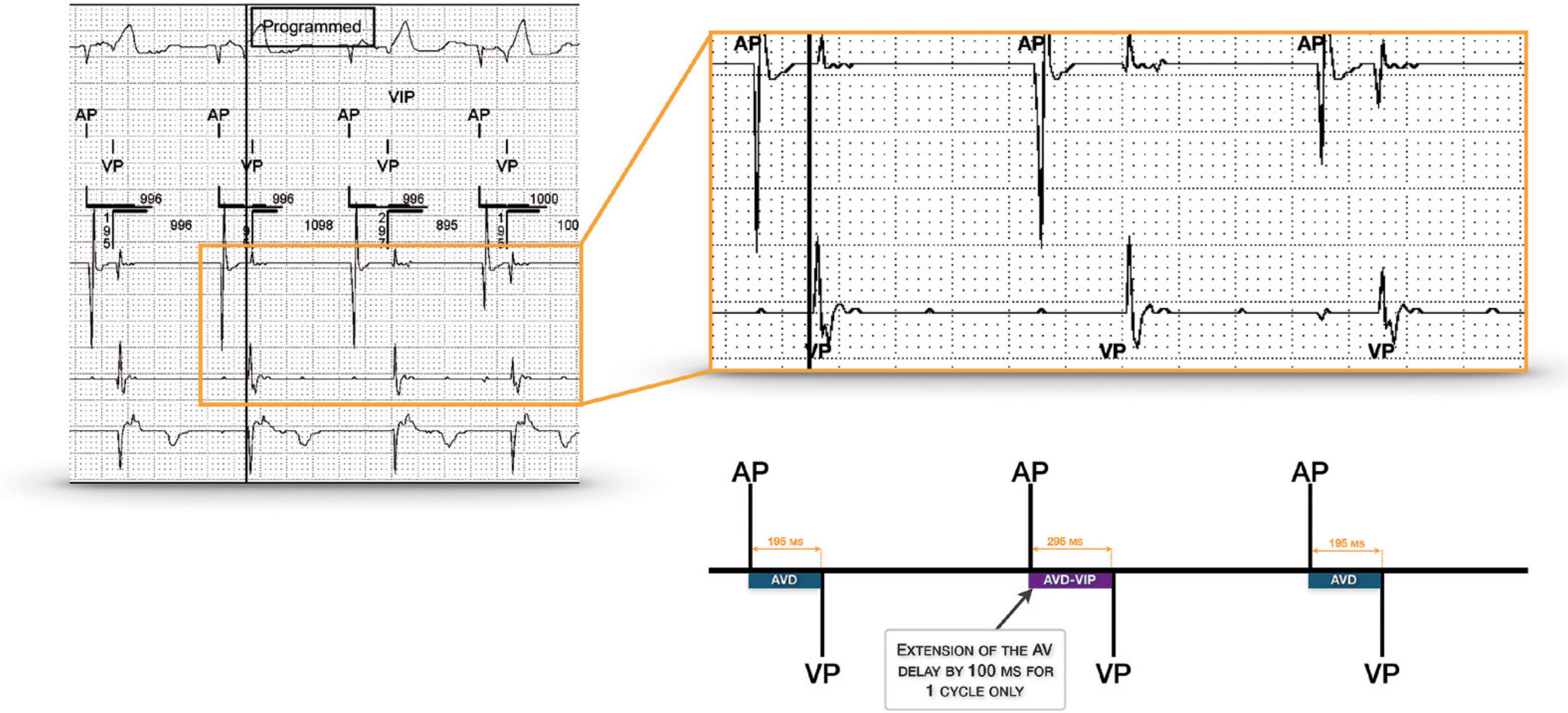
COMMENTS

These tracings illustrate the features of the VIP algorithm and its operation in a patient with atrioventricular conduction disorder. In order to favor the return of intrinsic conduction, the device temporarily extends its AV delay (up to a maximum of 450 ms). If no intrinsic ventricular event is sensed at the end of the prolonged AV period, ventricular pacing is delivered. Hence, there can be no blocked P wave during this search, given that ventricular pacing always occurs at the end of the prolonged AV delay in the absence of ventricular sensing. The main advantage of this algorithm is therefore to permanently maintain a 1:1 activation ratio between atria and ventricles. The search for intrinsic conduction is carried out only for rates below 110 bpm so as to avoid the occurrence of a 2:1 block during exercise in a patient with complete atrioventricular block. Indeed, the 2:1 point is dependent on the total atrial refractory period (AV delay + PVARP) which is substantially prolonged when searching for intrinsic conduction (very long AV delay). The temporary prolongation of the AV period can favor the occurrence of a PMT.

Three parameters are programmable necessitating a balance between effectiveness and risk of induction of a PMT: 1) VIP™ Extension which corresponds to the extension of the AV delay applied to the programmed AV delay (paced or sensed) to search for intrinsic conduction; the total value of the AV delay cannot exceed 450 ms; 2) the search interval corresponding to the time interval between each intrinsic conduction search which can be programmed to 30 seconds, 1, 3, 5, 10 or 30 minutes; increasing this value avoids iterative searches in a patient with permanent atrioventricular block; decreasing the value avoids unnecessary right ventricular pacing in a patient with short-term paroxysmal conduction disorder; 3) the number of consecutive cycles the device extends the AV delay to search for the occurrence of intrinsic conduction is programmable to 1, 2 or 3 cycles.

It is possible to view the atrioventricular conduction histogram in the pacemaker's memory. It is also possible to program a specific remote monitoring alert when the percentage of ventricular pacing exceeds a programmable threshold.

Three parameters are programmable in the VIP algorithm: 1) the VIP™ Extension which corresponds to the extension of the AV delay that is applied to the programmed AV delay; 2) the search interval corresponding to the time interval between each intrinsic conduction search; 3) the number of consecutive cycles with prolonged AV delay during which the search for intrinsic conduction occurs.


Programmed
VIP
AP
VP
996
1098
895
1000
100
195 ms
295 ms
AVD
AVD-VIP
Extension of the AV delay by 100 ms for 1 cycle only

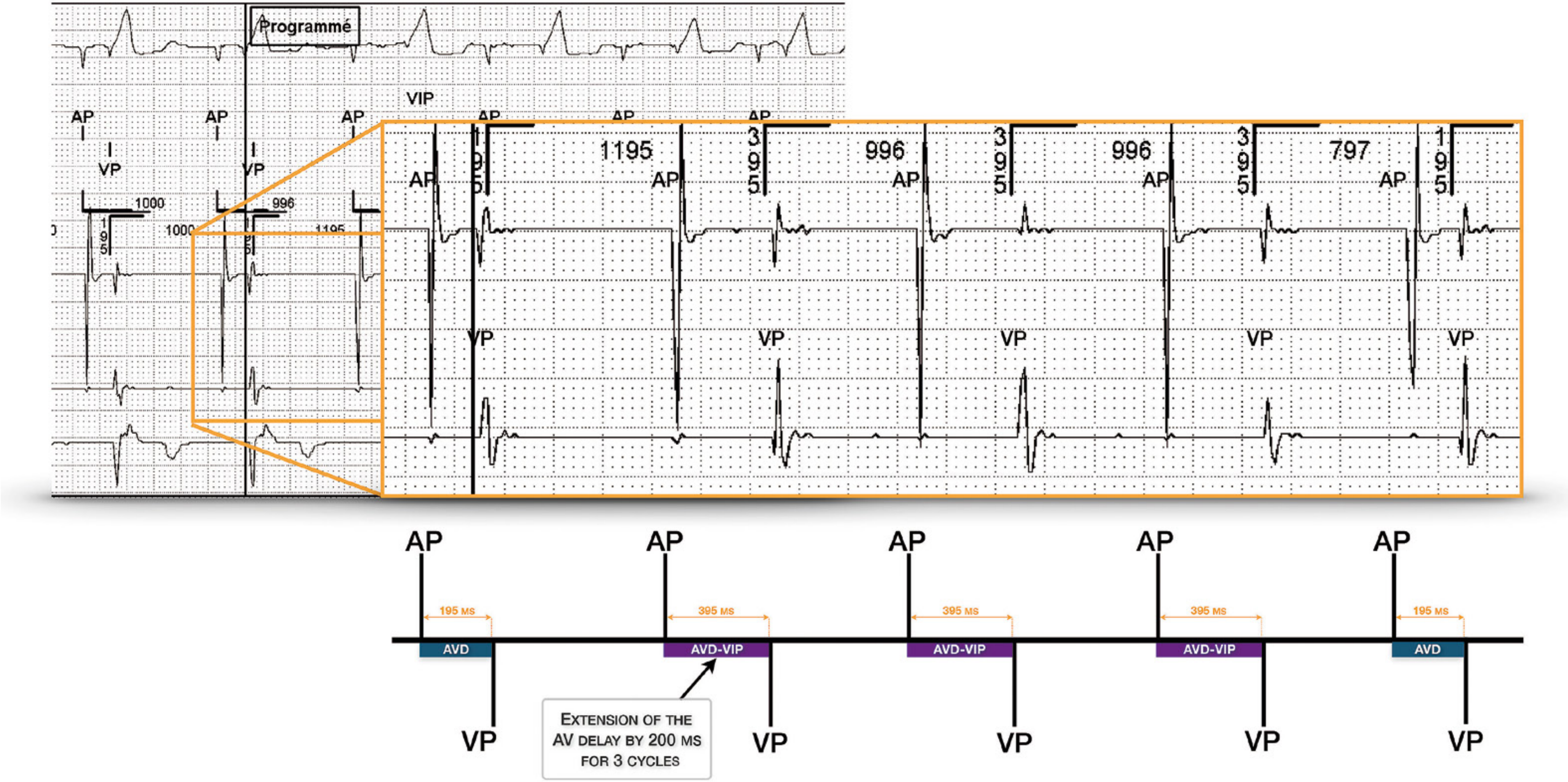
DDD-VIP mode

Tracing 12: pacing in DDD-VIP mode

SUMMARY

TRACING

Modification of the programming; prolongation of the AV delay of 200 ms for 3 cycles; absence of intrinsic ventricular activity and ventricular pacing; unsuccessful search and return to DDD mode pacing at the programmed AV delay.


Programmé
VIP
AP
VP
1000
996
1195
797
AP
AP
AP
AP
AP
VP
VP
VP
VP
VP
195 MS
395 MS
395 MS
395 MS
195 MS
AVD
AVD-VIP
AVD-VIP
AVD-VIP
AVD
EXTENSION OF THE AV DELAY BY 200 MS FOR 3 CYCLES

DDD-VIP MODE

Patient

72-year-old man implanted with an Assurity MRI™ pacemaker for paroxysmal atrioventricular block; programming of the VIP algorithm; recording of PMT episodes in the device memory.

Quiz

Which answer(s) is(are) true regarding this tracing?

A. the VIP is programmed with extension of the AV delay (100 ms)

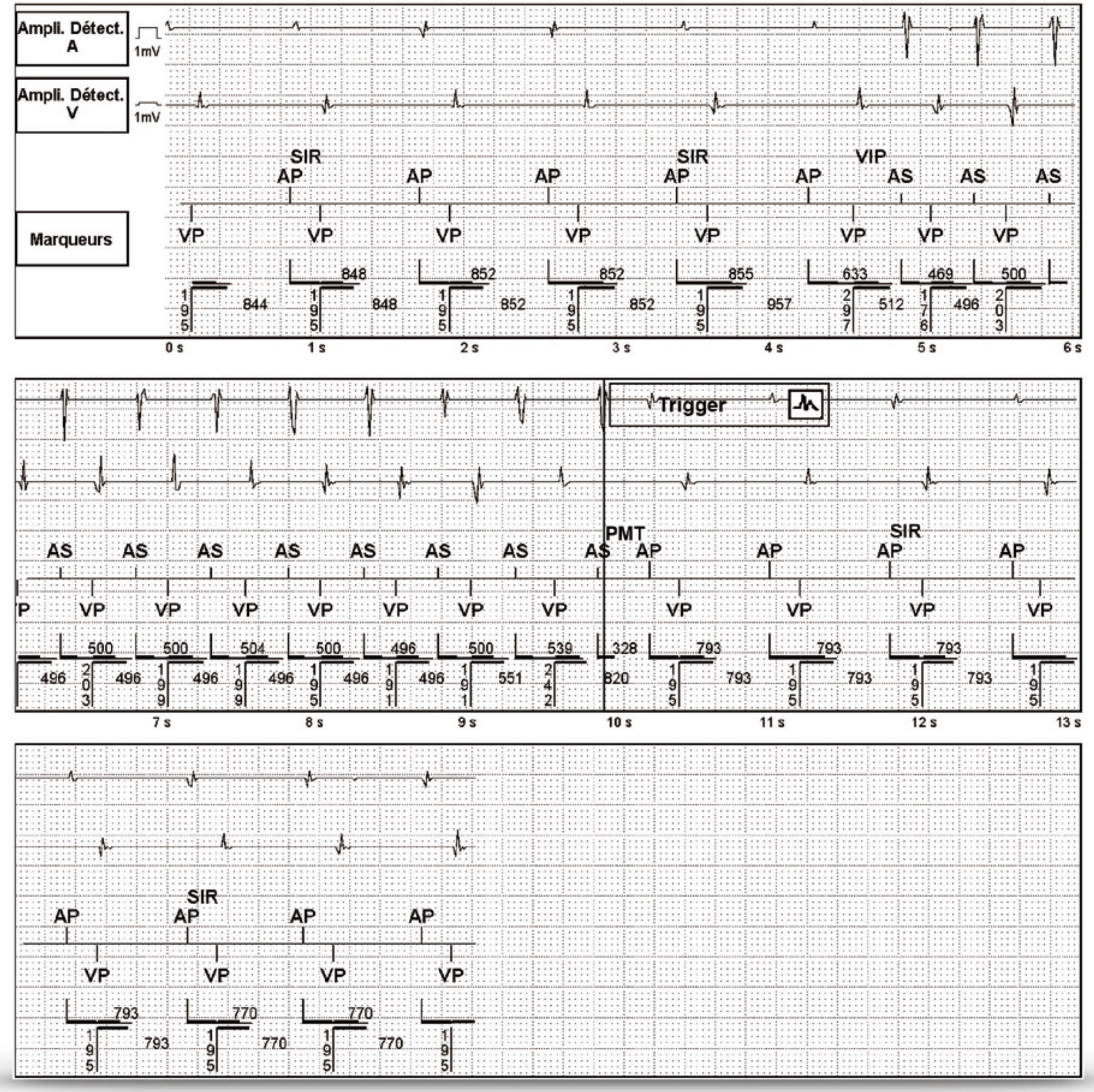
B. the VIP is programmed with extension of the AV delay for a single cycle

C. the extension of the AV delay favors the occurrence of retrograde atrial conduction

D. there is no retrograde conduction in this patient

E. this is an episode of spontaneously resolving atrial tachycardia

ANSWER(S)



AS Atrial sensing
AP Atrial pacing
VP Ventricular pacing

Tracing 13: VIP and risk of PMT

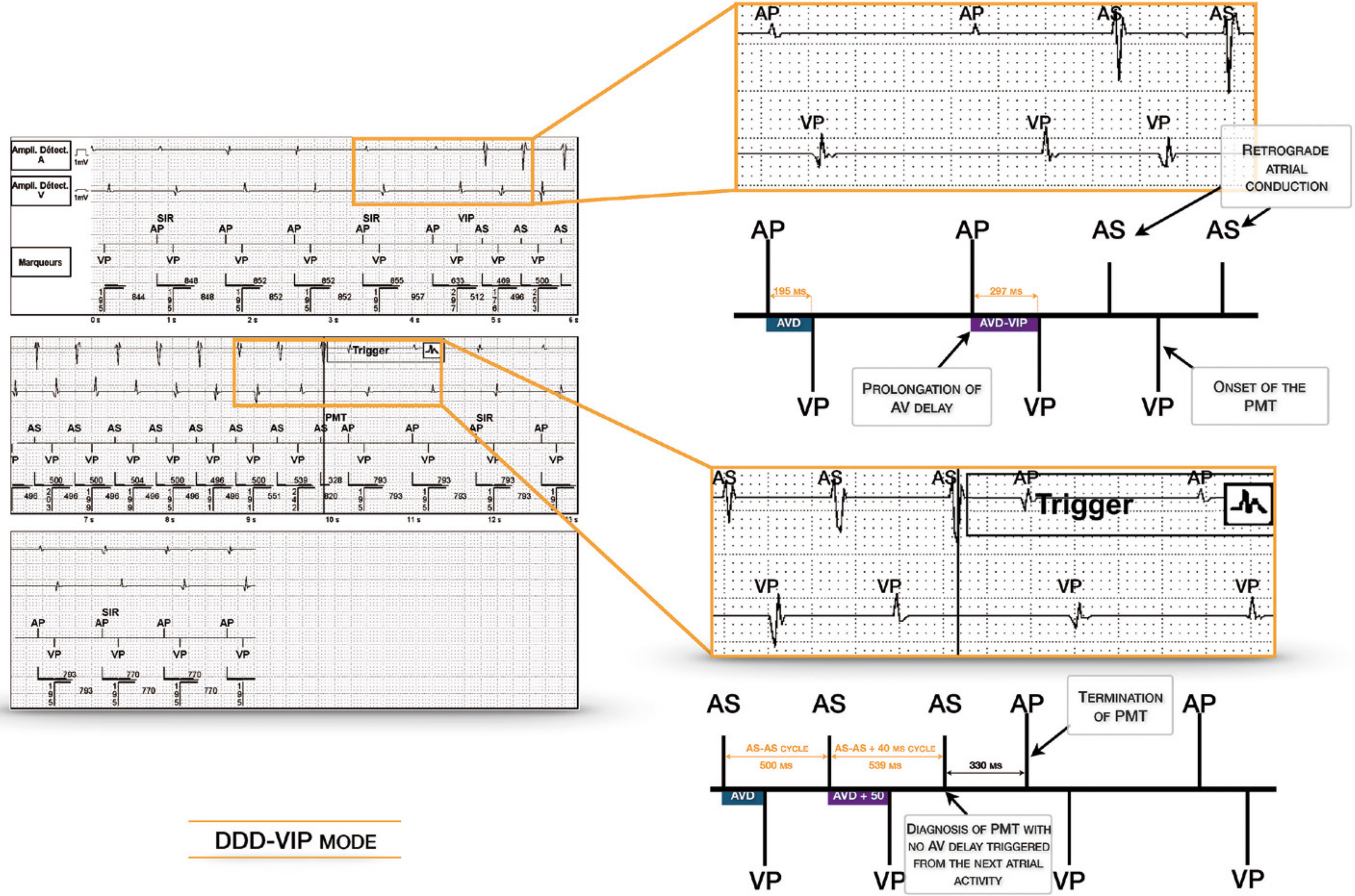
TRACING

Initially, the patient is paced in both the atrium and ventricle at the set rate response (sensor, SIR ratio); the device extends the AV delay for one cycle (from 195 to 297 ms, VIP programming: 1 cycle, extension of 100 ms); the prolongation promotes retrograde atrial conduction which is sensed outside the refractory periods (classified as AS) and triggers an AV delay; onset of a PMT; after 8 VP-AS cycles with VP-AS intervals and rate higher than the programmed PMT rate limit (110 beats/minute), suspicion of PMT by the device; extension of the AV delay of 50 ms (from 191 to 242 ms) on one cycle; on the next cycle, prolongation of the AS-AS cycle by approximately 40 ms, which demonstrates that the timing of atrial activity is contingent on the timing of ventricular pacing (in favor of a PMT relative to sinus tachycardia); the next atrial activity does not trigger an AV delay; atrial pacing 330 ms after the last AS cycle followed by ventricular pacing; termination of the tachycardia confirming the diagnosis of PMT.

COMMENTS

As explained previously, when the VIP is programmed, the search for intrinsic conduction is based on an AV delay hysteresis with an extended AV delay, during 1 to 3 cycles, with a maximum value of 450 ms. There can therefore be no P waves blocked during this search thus avoiding ventricular pauses that may be symptomatic or, in a few rare patients, favor the occurrence of ventricular arrhythmias. When there is a permanent or paroxysmal atrioventricular conduction disorder, as in this patient, this search is ultimately unsuccessful with a subsequent return to the DDD mode at the programmed AV delay. One of the limitations of this option is that, in patients with impaired anterograde conduction but preserved retrograde conduction, prolongation of the AV delay can favor the occurrence of retrograde conduction able to trigger a pacemaker-mediated tachycardia without the need of other triggering factors (premature atrial or ventricular contraction, loss of atrial capture, etc). The number of PMTs can therefore be very significant when increasing the AV delay induces retrograde conduction. The simplest and most logical approach in the presence of a complete permanent atrioventricular block is not to program the VP-suppression algorithm. When the conduction disorder is paroxysmal and when preserving intrinsic conduction appears desirable, it is then essential to verify that the PVARP is appropriately programmed longer than the retrograde conduction time.

In patients with impaired anterograde atrioventricular conduction but preserved retrograde atrial conduction, it is advisable not to program the VIP so as not to increase the risk of PMT.



Ampli. Détect. A
Ampli. Détect. V
Marqueurs
Trigger
PMT
Retrograde atrial conduction
AP
AS
VP
195 ms
297 ms
AVD
AVD-VIP
Prolongation of AV delay
Onset of the PMT
Termination of PMT
AS-AS cycle 500 ms
AS-AS + 40 ms cycle 539 ms
330 ms
AVD + 50
Diagnosis of PMT with no AV delay triggered from the next atrial activity

DDD-VIP mode

CHAPTER 2

Pacing and capture

Patient

87-year-old man implanted with an Accent™ DR pacemaker for symptomatic slow AF; a few months after implantation, fatigue, dyspnea and lipothymia.

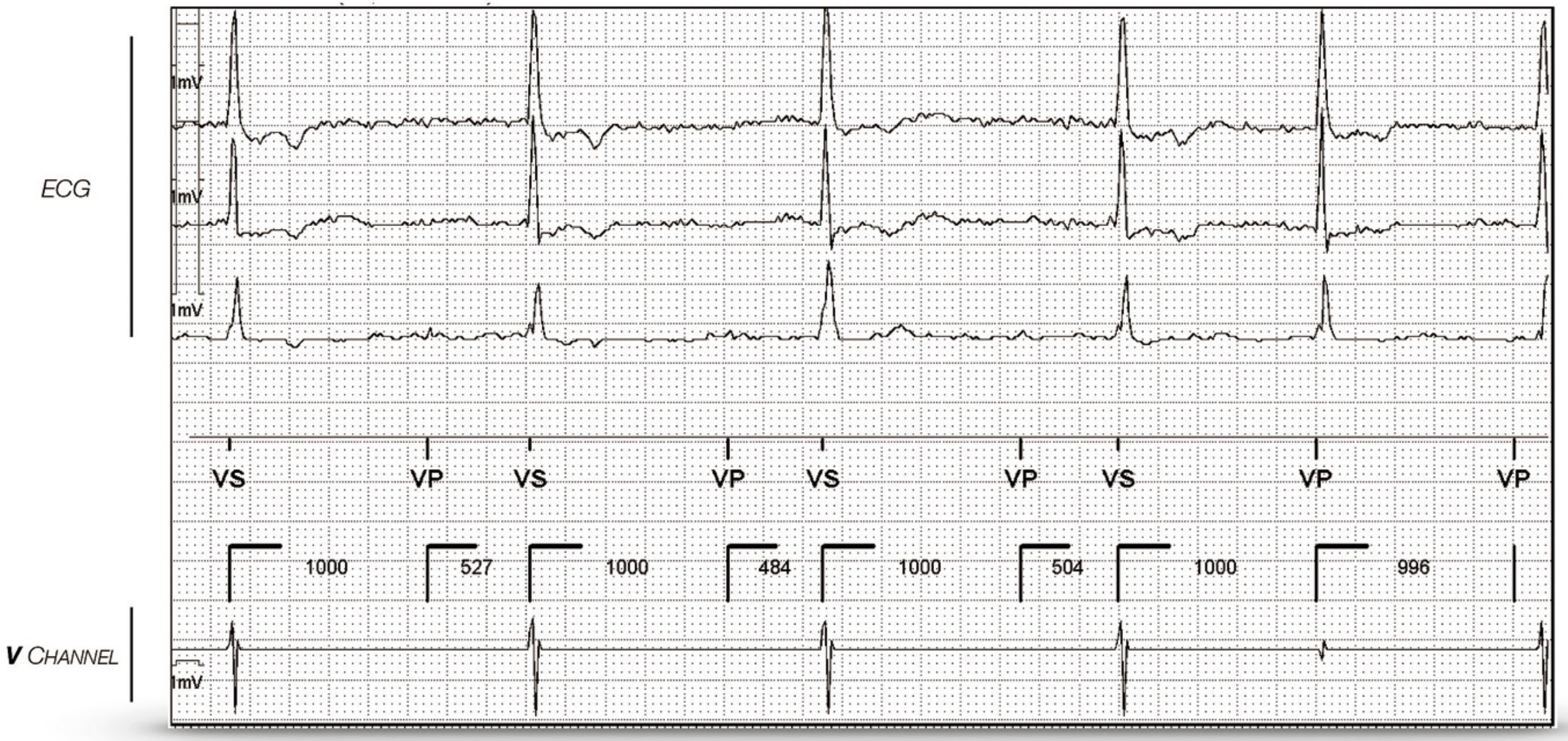
Quiz

Which answer(s) is(are) true regarding this tracing?

A. the pacing mode is VVI 60 beats/minute
B. the pacing mode is VVI 70 beats/minute
C. there is a failure of right ventricular capture
D. there is a failure of ventricular sensing
E. the intrinsic rhythm of the patient is a complete atrioventricular block

ANSWER(S)

Pacing and capture



VS Ventricular sensing
VP Ventricular pacing

Tracing 14: loss of right ventricular capture

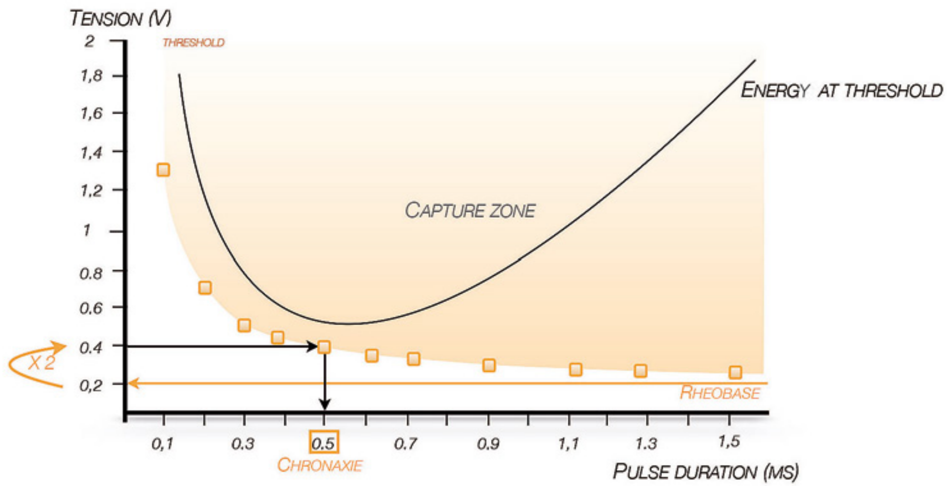
TRACING

The pacemaker is set in VVI mode 60 beats/minute (VS-VP interval of 1000 ms); proper sensing of intrinsic QRS; failure of ventricular capture; atrial fibrillation with altered although still present atrioventricular conduction (irregular intrinsic QRS).

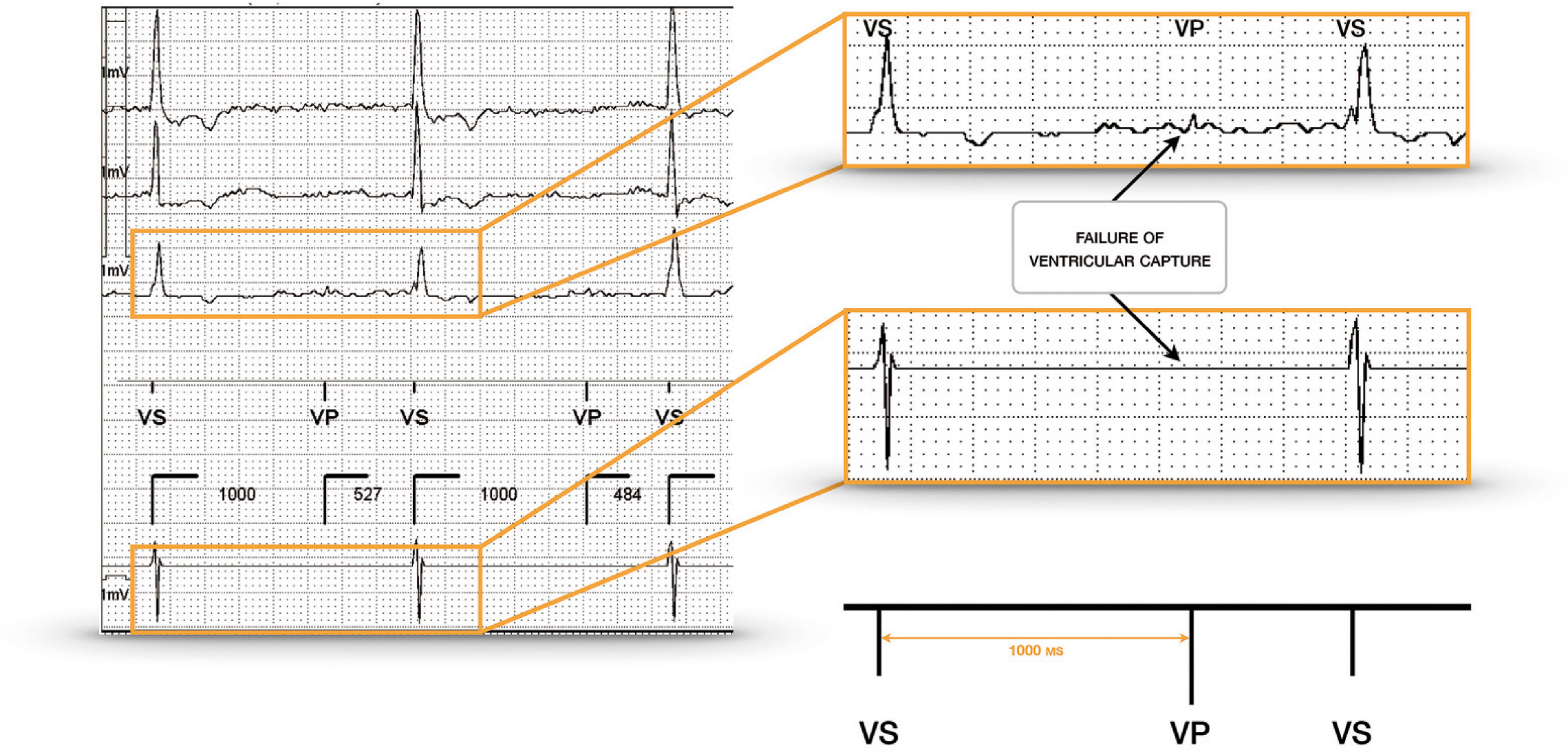
COMMENTS

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

This tracing reveals a loss of ventricular capture in a patient with chronic AF and impaired atrioventricular conduction. This patient was programmed with a ventricular pacing amplitude of 2.5 Volts for 0.5 ms. His symptomatology was highly suggestive, with a return to clinical signs observed in pre-implantation (fatigue, dyspnea, lipothymia). There was no obvious cause (drug, metabolic, macro-dislodgement of the lead, etc) to explain the increase in threshold (measured at 3 Volts for 0.5 ms). Given this elevation in threshold, the programming of the automatic pacing output adjustment should be evoked. Indeed, it is possible to program, in all contemporary pacemakers, an automatic ventricular threshold measurement function more or less associated with an automatic adjustment of the pacing amplitude.



The Lapicque relationship describes the nonlinear relationship of the threshold voltage relative to pulse duration. The rheobase is the lowest effective voltage for an indefinite pulse duration (in practice, > 2 ms). Chronaxie is the minimum effective pulse duration needed for twice the rheobase voltage. The energy consumed is minimal for a pulse duration corresponding to the chronaxie. Chronaxie and rheobase electrically describe a pacing electrode. Today, chronaxie values range between 0.3 and 0.4 ms regardless of the lead used.


1mV
1mV
1mV
VS
VP
VS
VP
VS
1000
527
1000
484
1mV
VS
VP
VS
FAILURE OF
VENTRICULAR CAPTURE
1000 ms
VS
VP
VS

Patient

78-year-old man implanted with an Accent™ DR pacemaker for paroxysmal atrioventricular block; measurement of the right ventricular pacing threshold during the consultation.

Quiz

Which answer(s) is(are) true regarding this tracing?

A. this is a manual ventricular threshold measurement by the operator

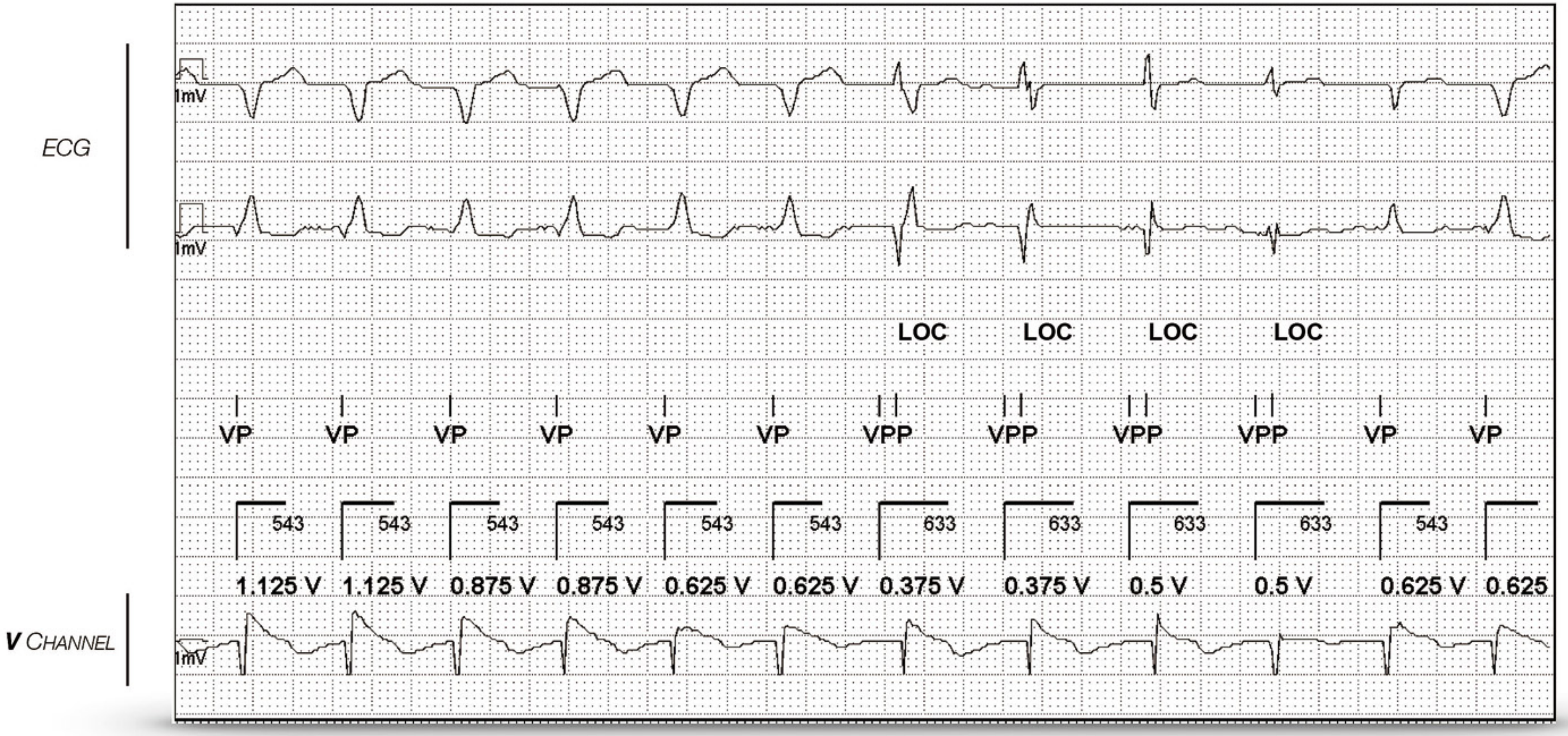
B. this is an automatic ventricular threshold measurement by the device

C. the ventricular threshold measurement is based on the analysis of the evoked response

D. the threshold value is measured at 0.5 V

E. the threshold value is measured at 0.625 V

ANSWER(S)



VP Ventricular pacing

Tracing 15: ventricular AutoCapture™

TRACING

This is an automatic right ventricular pacing threshold measurement; initially, the pacing amplitude decreases in steps of 0.250 V every 2 cycles; up to 0.625 V, capture is effective; at the next step, the device diagnoses a loss of capture (LOC) and delivers a 5 V safety pulse (programmed pulse duration), 80 to 100 ms after the first noncapture; the device subsequently increases the amplitude in steps of 0.125 V; pacing remains ineffective at 0.5 V with recovery of an effective capture at 0.625 V which corresponds to the threshold value.

COMMENTS

There is a long history of the use of ventricular AutoCapture™ on St. Jude Medical™ and Abbott™ pacemakers.

Certain key principles should be kept in mind:

1) for the older pacemakers (Microny™, Victory™ and prior models), a bipolar ventricular lead was needed for programming ventricular AutoCapture™ (bipolar sensing and unipolar pacing); for the newer devices, ventricular AutoCapture™ can be activated regardless of the programmed sensing and pacing configurations;

2) an automatic Autocapture™ setup test, used to verify the compatibility of the lead according to its polarization as well as to differentiate capture from capture failure, precedes the first activation of the device; this test remains optional (although recommended) before each threshold measurement; the use of ventricular AutoCapture™ is only recommended when the amplitude of the polarization signal is less than 4 mV, when the safety margin between the amplitude of the evoked response signal and the sensitivity setting of the evoked response is at least 1.8 and when the safety margin between the amplitude of the polarization signal and the sensitivity setting of the evoked response is at least 1.7;

3) the automatic threshold measurement is based on the analysis of the evoked ventricular response;

4) the ventricular threshold is periodically measured at minimum every 8 to 24 hours (programmable value);

5) the ventricular pacing amplitude is automatically adjusted with a fixed and non-programmable safety margin of 0.25 V; this algorithm functions irrespectively of the programmed pulse duration;

6) the maximum delivered amplitude (outside of the backup pacing) is 3.875 V for the programmed pulse duration;

7) there is a cycle-to-cycle control of ventricular capture efficiency;

8) in the event of a loss of capture, a 5 V backup pulse is delivered 80 to 100 ms after the first stimulus.

Ventricular AutoCapture™ relies on a periodic automatic ventricular threshold measurement based on the analysis of the evoked ventricular response and a cycle-to-cycle control of capture efficiency. The ventricular pacing amplitude is automatically adjusted with a fixed and non-programmable safety margin of 0.25 V.

There are 3 available settings for ventricular AutoCapture™:

1) Setup: this setting is available during the initial activation; the programmer then proposes to start the Setup test followed by the Pacing test if AutoCapture is recommended;

2) On: the device measures the threshold, automatically adjusts the pacing amplitude and records the threshold measurement in the Threshold Curve and stores the EGM corresponding to the last threshold;

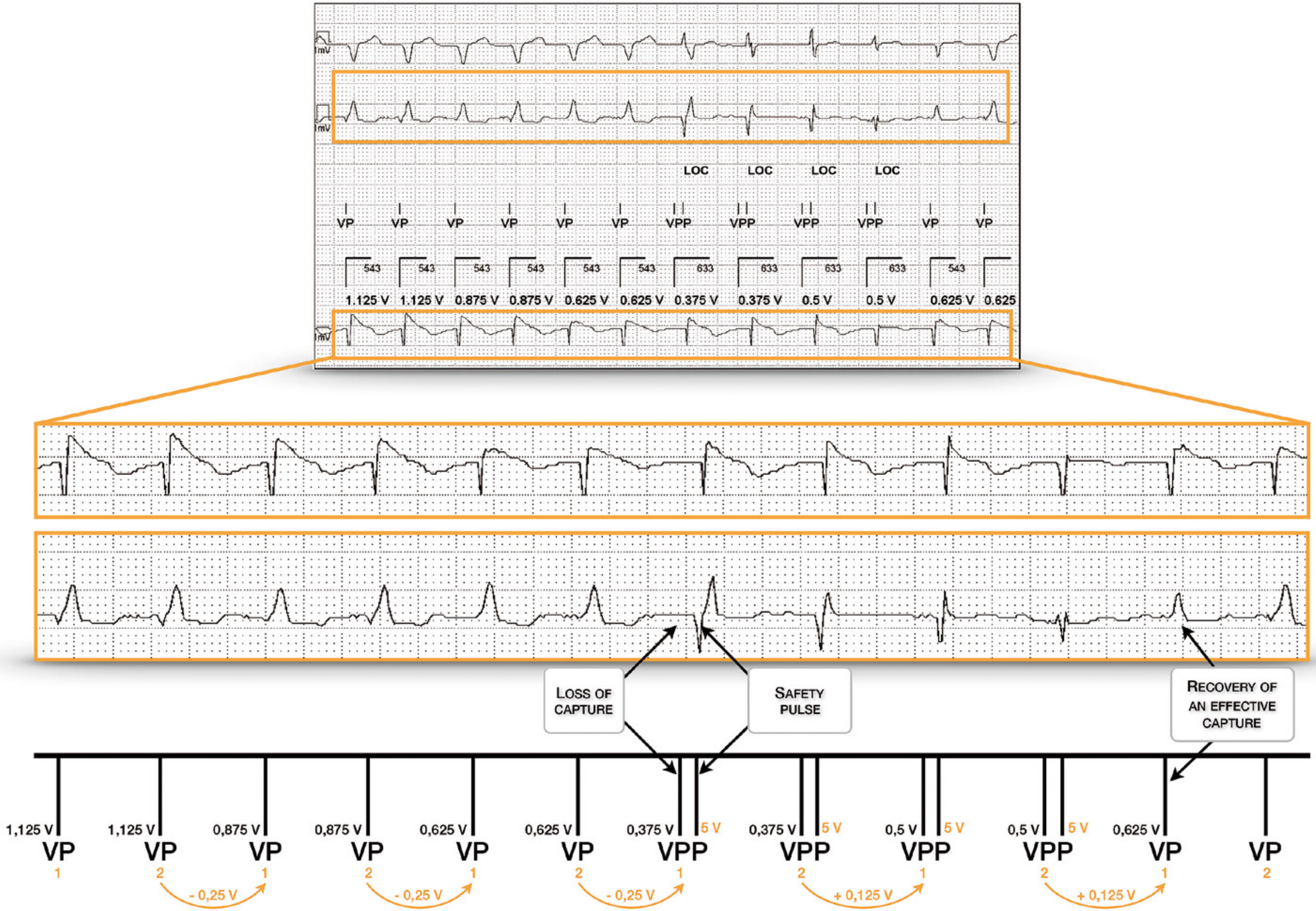
3) Off: the device does not measure the pacing threshold and does not perform any automatic adjustment of the pulse amplitude.

The following settings are adjustable in the Auto Capture Settings window:

1) the configuration of the backup pulse which allows programming the polarity configuration of the backup safety pulse to the bipolar or unipolar mode bipolar (nominal value) or unipolar mode; (Unipolar is the nominal value only if the RV lead is set on unipolar);

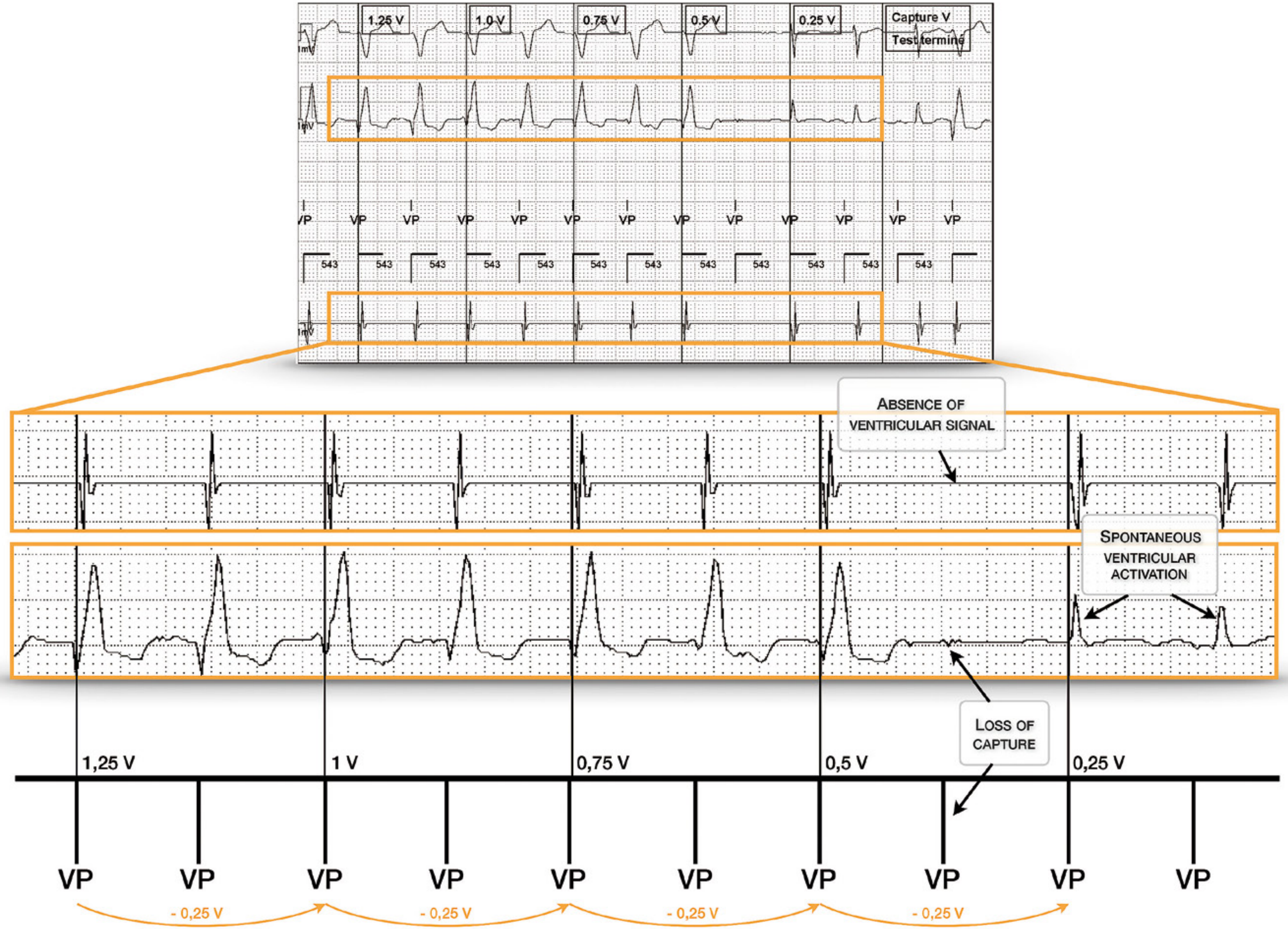
2) the search interval that programs the periodicity of the 8-hour (nominal value) or 24-hour threshold measurement;

3) the paced/sensed AV delays that determine the paced AV Delay and sensed AV Delay settings used during a threshold search to 50/25 ms (nominal value), 100/70 ms or 120/100 ms; the recommended setting for this parameter is 50/25 to prevent fusions; a fusion with intrinsic activation is more likely with longer programmed delays and can result in inaccurate threshold search results.


LOC LOC LOC LOC
VP VP VP VP VP VP VPP VPP VPP VPP VP VP
543 543 543 543 543 543 633 633 633 633 543
1.125 V 1.125 V 0.875 V 0.875 V 0.625 V 0.625 V 0.375 V 0.375 V 0.5 V 0.5 V 0.625 V 0.625
Loss of capture
Safety pulse
Recovery of an effective capture
1,125 V VP 1
1,125 V VP 2
0,875 V VP 1
0,875 V VP 2
0,625 V VP 1
0,625 V VP 2
0,375 V 5 V VPP 1
0,375 V 5 V VPP 2
0,5 V 5 V VPP 1
0,5 V 5 V VPP 2
0,625 V VP 1
VP 2
- 0,25 V
- 0,25 V
- 0,25 V
+ 0,125 V
+ 0,125 V

TRACING

Threshold measurement performed manually in the same patient; effective capture at 0.75 V and loss of capture at 0.5 V confirming the validity of the automatic threshold measurement.


1.25 V
1.0 V
0.75 V
0.5 V
0.25 V
Capture V
Test termine
VP
543
ABSENCE OF VENTRICULAR SIGNAL
SPONTANEOUS VENTRICULAR ACTIVATION
LOSS OF CAPTURE
1,25 V
1 V
0,75 V
0,5 V
0,25 V
VP
- 0,25 V

Patient

69-year-old man implanted with an Accent™ DR pacemaker for complete atrioventricular block; programming of ventricular AutoCapture™; interrogation of the pacemaker and analysis of the monitoring curves of the automatic ventricular threshold measurement.

Quiz

Which answer(s) is(are) true regarding ventricular AutoCapture™?

A. in the most recent pacemakers, ventricular AutoCapture™ is only programmable with a bipolar lead

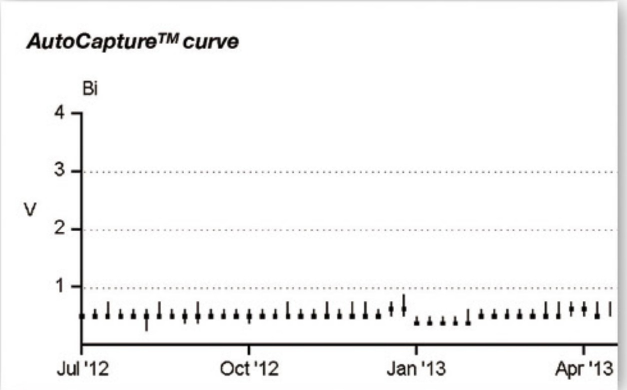
B. the ventricular pacing threshold is automatically measured every 20 hours

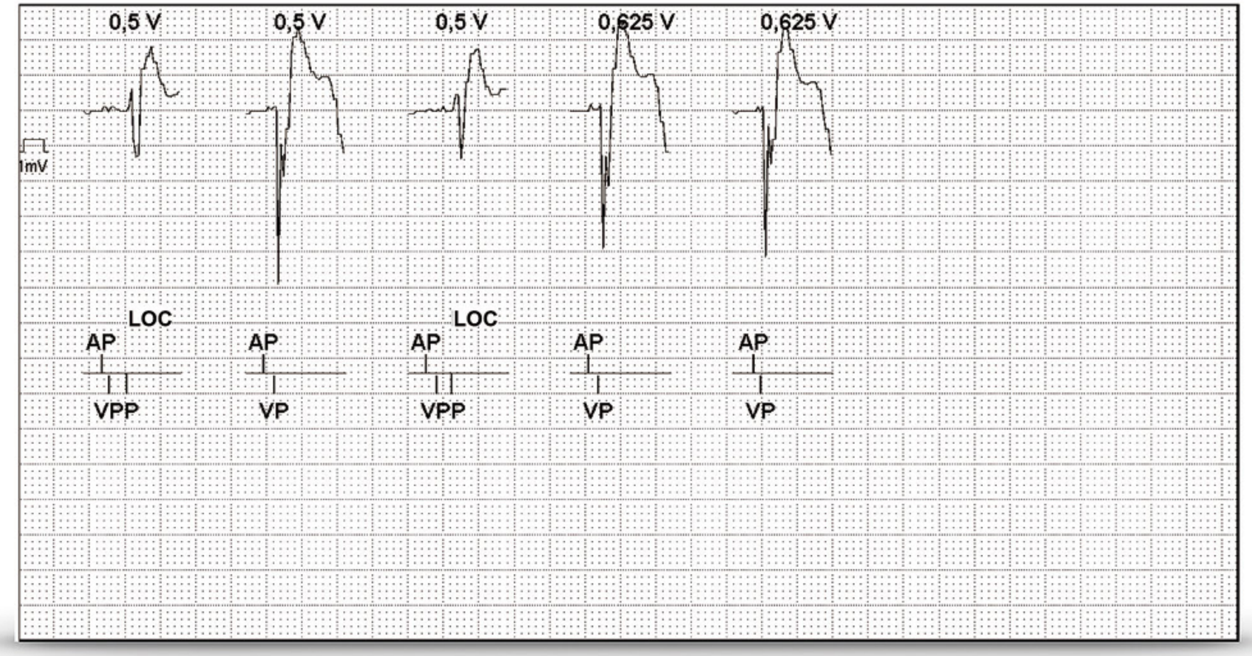
C. in the event of loss of capture, a 5 V backup pulse is delivered 80 to 100 ms after the first stimulus

D. the ventricular pacing amplitude is automatically adjusted with a programmable safety margin between 0.25 V and 1.5 V

E. the pacemaker automatically adjusts the delivered amplitude and pulse duration

ANSWER(S)





AP Atrial pacing
VP Ventricular pacing

Tracing 17: ventricular AutoCapture™ and automatic ventricular threshold measurement

TRACING

The AutoCapture™ curve shows low (<1 V) and regular ventricular threshold values; the tracing of the last automatic measurement shows an intermittent loss of capture at 0.5 V and an effective capture at 0.625 which therefore constitutes the ventricular threshold value.

COMMENTS

The device uses 4 complementary algorithms for the functioning of ventricular AutoCapture™:

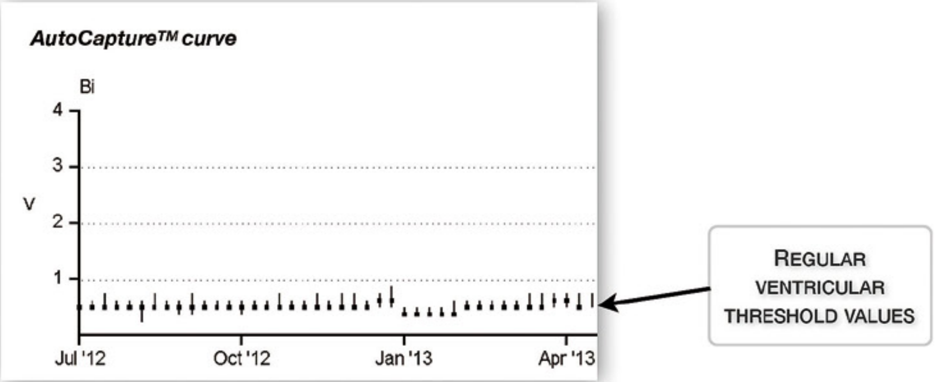
1) Capture confirmation which is based as explained previously on an analysis of the Evoked Response; if a ventricular pacing configuration is programmed to bipolar mode, the area under the curve is used (Paced Depolarization Integral); if a ventricular pacing configuration is programmed to unipolar mode, the signal slope (DMAX) is used; to verify the presence of the capture, there is an initial blanking period of 14 ms followed by an evoked response detection window of 46 ms; if the device detects an evoked response in this window, the capture is confirmed; if no evoked response signal is sensed, the device emits a 5 V backup pulse within 80 to 100 ms after the initial pulse to ensure capture;

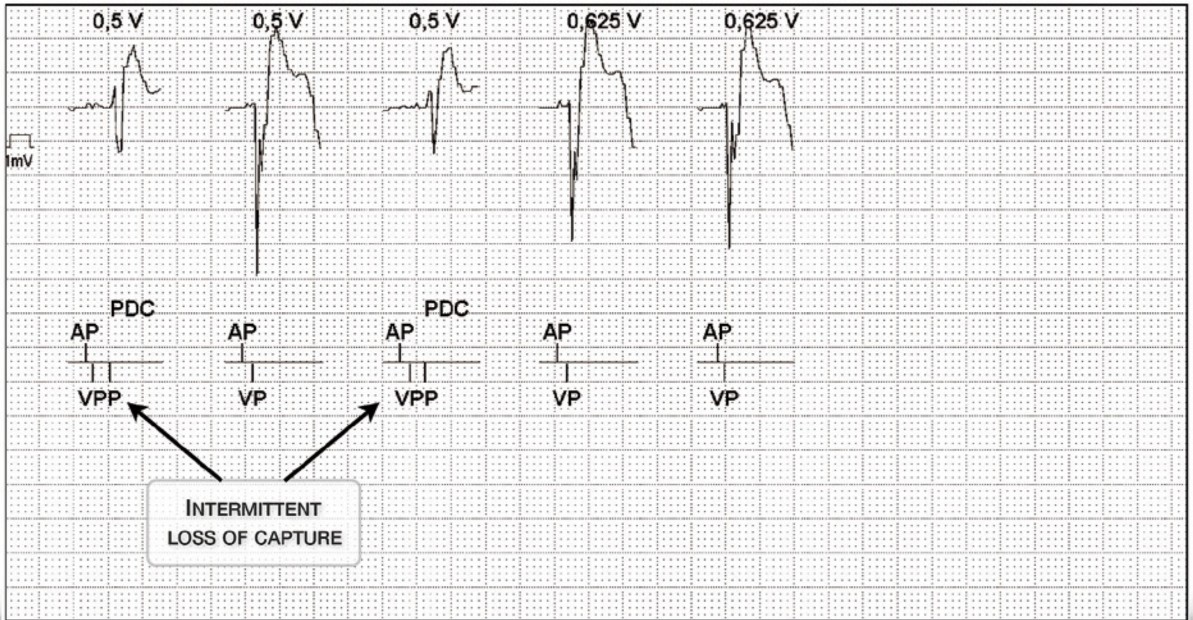
2) Loss of capture Recovery; if capture verification confirms two consecutive losses of capture, the device launches the loss of capture recovery algorithm; on the ensuing cycle, the pacemaker delivers a backup pulse and then increases the automatic pulse amplitude by 0.25 V and searches for a capture; if no capture is confirmed a backup pulse is delivered and, the device increases the pulse amplitude by 0.125 V on the next cycle and searches for the capture; when two successive captures are confirmed at the same voltage, the apparatus begins a threshold search; if no capture is confirmed before the device automatically increases the pulse amplitude to 3.875V, the device switches to High output mode: the pulse amplitude is set to 5V and the duration pulse to 0.5 ms (or longer if the programming value is higher); after 128 cycles, the device reinitiates a threshold search;

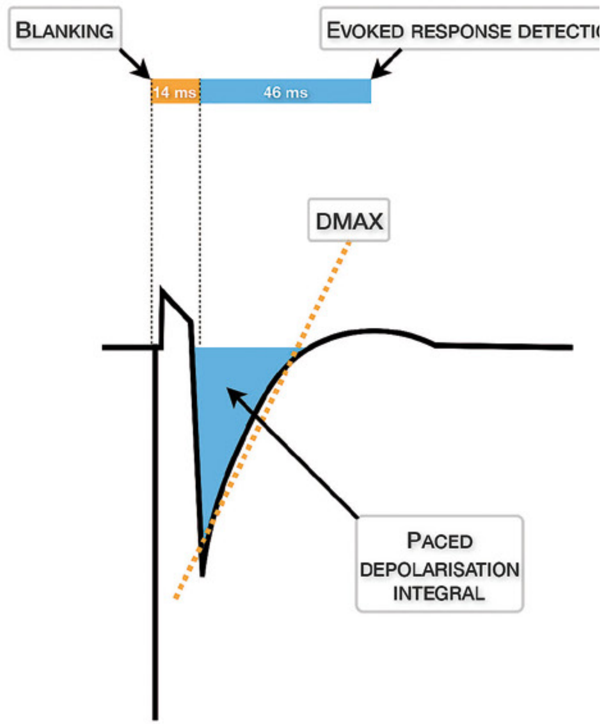
3) Fusion avoidance: fusions with intrinsic activation can skew threshold measurements with untimely activation of the loss of capture recovery algorithm; in dual-chamber mode, a single absence of evoked response sensing, requiring the delivery of a 5 V backup pulse, automatically causes the next cycle to prolong the paced and sensed AV delay by 100 ms in order to search for intrinsic conduction; in first line treatment, the algorithm « makes the assumption » that the loss of capture is due to a fusion and not to a lack of pulse strength; this function acts in a manner similar to VIP™; if the loss of capture is confirmed after extending the paced or sensed AV delay (2 consecutive beats requiring the delivery of a 5-V safety pulse), the pacemaker triggers its capture recovery algorithm;

4) Periodic measurement of the pacing threshold: to automatically determine the pacing threshold, the device decreases the pulse amplitude by 0.25 V every two cycles; if this leads to a loss of capture, the device emits a 5 V backup pulse (safety margin) 80 to 100 ms after the first test pulse; in the event of loss of capture over two consecutive cycles at the same amplitude, the algorithm then increases the pulse amplitude in steps of 0.125 V every two cycles; two consecutive captures at the same amplitude must be confirmed to determine the new pacing threshold value; if the decremental search fails to determine a loss of capture at the lowest pulse amplitude setting, i.e. 0 V, the device switches to « High output mode » for a duration of 128 cardiac cycles, then reinitiates the threshold search; if the pacing threshold determined by the algorithm exceeds 3.875 V for a given pulse duration, the ventricular AutoCapture™ is automatically deactivated and the amplitude is reprogrammed to 5 V (High output mode); the threshold search is repeated a) after each loss of capture recovery operation, b) automatically every 8 hours, c) upon removal of the telemetry head, d) upon removal of the magnet, e) when the operator performs the pacemaker Autocapture™ threshold test.

The programming of ventricular AutoCapture™ enables 1) regular monitoring of pacing thresholds, 2) a reduction in battery consumption (margin of only 0.25V compared to the measured value), 3) a gain in terms of safety in pacemaker-dependent patients presenting significant threshold variations within the capacity limits of the algorithm (3.875 V for the programmed pulse duration).







Analysis of the Evoked Response

SUMMARY

Patient

76-year-old man implanted with an Accent MRI™ pacemaker for complete atrioventricular block; recording of this tracing during the consultation.

Quiz

Which answer(s) is(are) true regarding this tracing?

A. there is a failure of atrial sensing

B. there is a failure of atrial capture

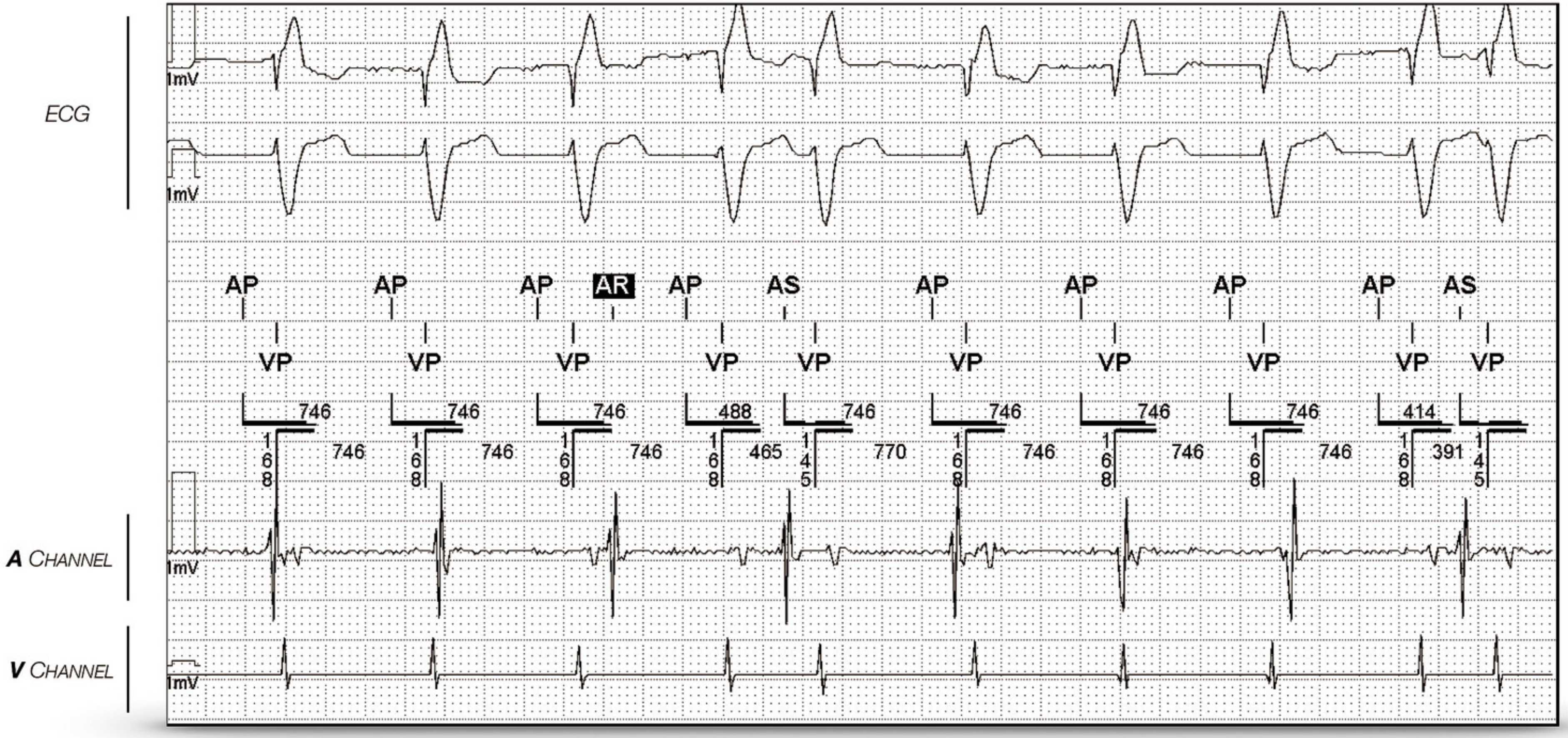
C. there is a retrograde atrial conduction

D. there is an onset of PMT

E. there is presence of crosstalk

ANSWER(S)

SUMMARY


ECG
A CHANNEL
V CHANNEL
1mV
AP
AR
AS
VP
746
488
414
465
770
391
168
145

AS Atrial sensing
AP Atrial pacing
VP Ventricular pacing

Tracing 18: loss of atrial capture

SUMMARY

TRACING

The atrial EGM reveals the presence of regular intrinsic atrial activity unaffected by atrial pacing; there is a clear failure of atrial capture; P waves are sensed when they fall within the PVARP (AR) or outside of any refractory period (AS); in the latter case, atrial sensing triggers an AV delay and ventricular pacing; the atrial activities are not sensed when they fall during the AV delay (on the AP-VP cycles) or during post-ventricular atrial blanking which consists of 2 absolute atrial refractory periods.

COMMENTS

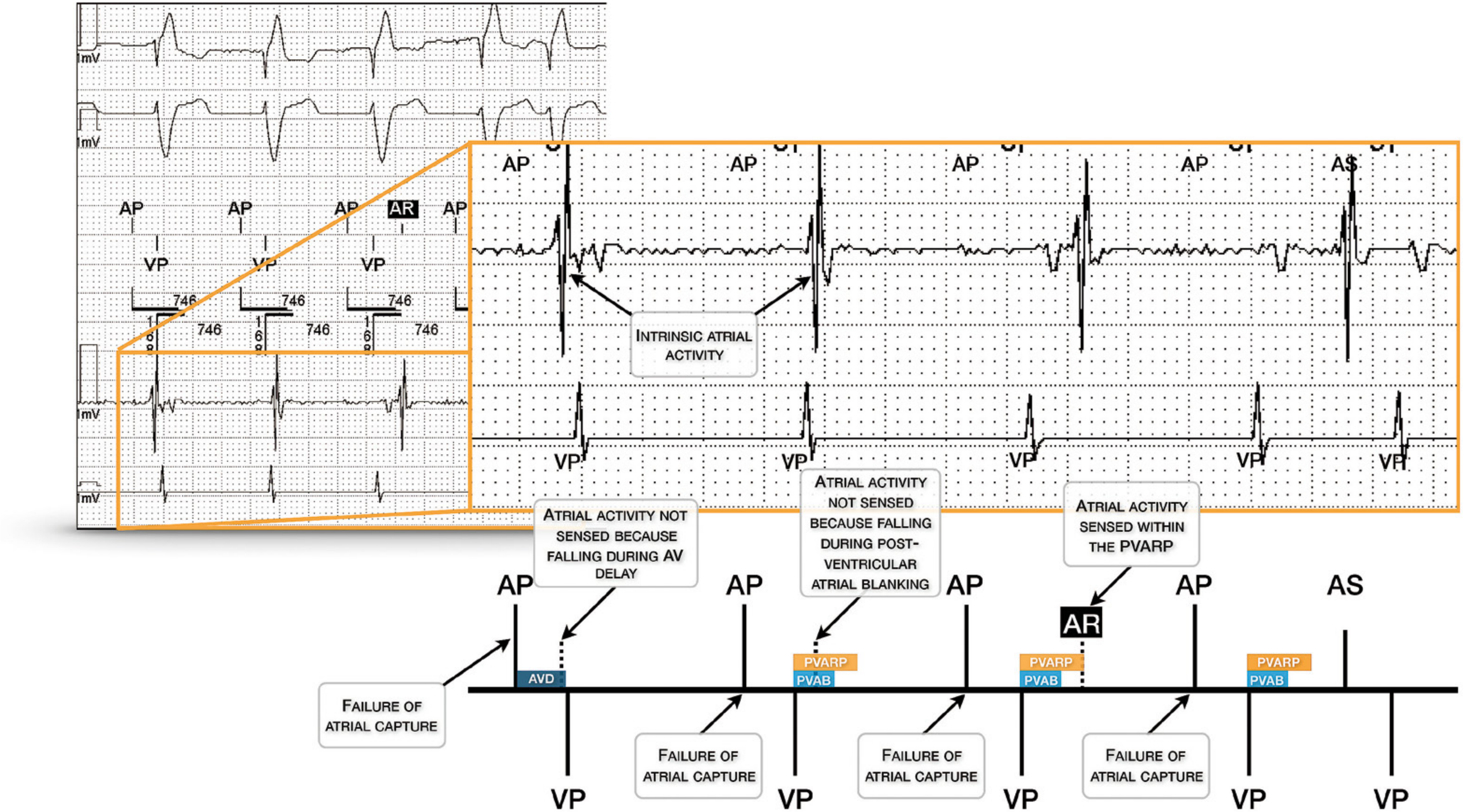
This tracing reveals a failure of atrial capture. The atrial output amplitude was programmed in this patient at 2.5 Volts for a pulse duration of 0.5 ms. The pacing threshold had passed beyond this value (threshold at 3 Volts for 0.5 ms) thus explaining the loss of capture. The temporary increase in output amplitude to 4 Volts for 0.4 ms allowed resolving the problem. This tracing raises the question of programming the automatic adjustment of the atrial pacing amplitude (ACap™ Confirm).

There are a number of commonalities as well as differences in the functioning of atrial ACap™ Confirm and ventricular AutoCapture™. The algorithm uses the morphology of the analysis of the evoked atrial response between the atrial distal electrode and the pulse generator to automatically measure the atrial threshold. The output amplitude is adjusted automatically but without cycle-to-cycle verification and with a non-programmable and variable margin depending on the value of the threshold. Atrial pacing must be programmed in bipolar mode.

Different parameters are programmable: 1) ON (periodic threshold measurements, indexed data and automatic adjustment of the atrial pacing amplitude), MONITOR (periodic threshold measurements, indexed data but no amplitude adjustment), OFF; 2) Search interval: 8h or 24h; the pacing amplitude is hence adjusted for the next 8 or 24 hours.

The safety margin varies according to the threshold: if the atrial threshold is less than 1.5V, the margin is 1.0V; if the threshold is between 1.625V and 2.25V, the margin is + 1.5V; if the threshold is between 2.375V and 3.0V, the margin is 2.0V; if the threshold is greater than 3V, the amplitude delivered is 5V.

Abbott™ pacemakers allow an automatic measurement of the atrial pacing threshold along with adjustment of the programming. The threshold is measured every 8 or 24 hours based on the analysis of the morphology of the evoked atrial response. There is no cycle-to-cycle verification of the effectiveness of the capture, but programming of a fixed and variable safety margin according to the threshold between the two measurements.



Intrinsic atrial activity
Atrial activity not sensed because falling during AV delay
Atrial activity not sensed because falling during post-ventricular atrial blanking
Atrial activity sensed within the PVARP
Failure of atrial capture
Failure of atrial capture
Failure of atrial capture
Failure of atrial capture
AP
AP
AP
AP
AS
AR
AVD
PVARP
PVAB
VP
VP
VP
VP
VP
746
1mV

Patient

83-year-old man implanted with an Assurity MRI™ pacemaker for syncopal atrioventricular block; programming of ACap™ Confirm; interrogation of the pacemaker and analysis of the automatic atrial threshold measurement curves.

Quiz

Which answer(s) is(are) true for atrial ACap™ Confirm?

A. capture control is based on the morphology analysis of the evoked atrial response

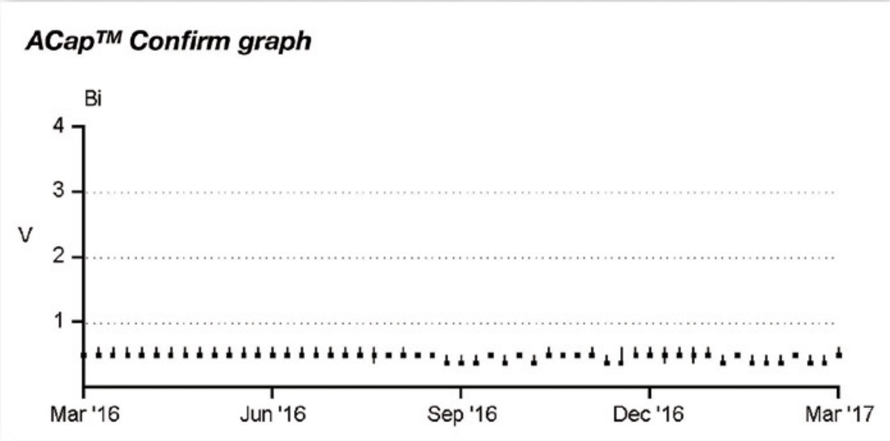
B. the maximum amplitude that can be delivered is 5 Volts

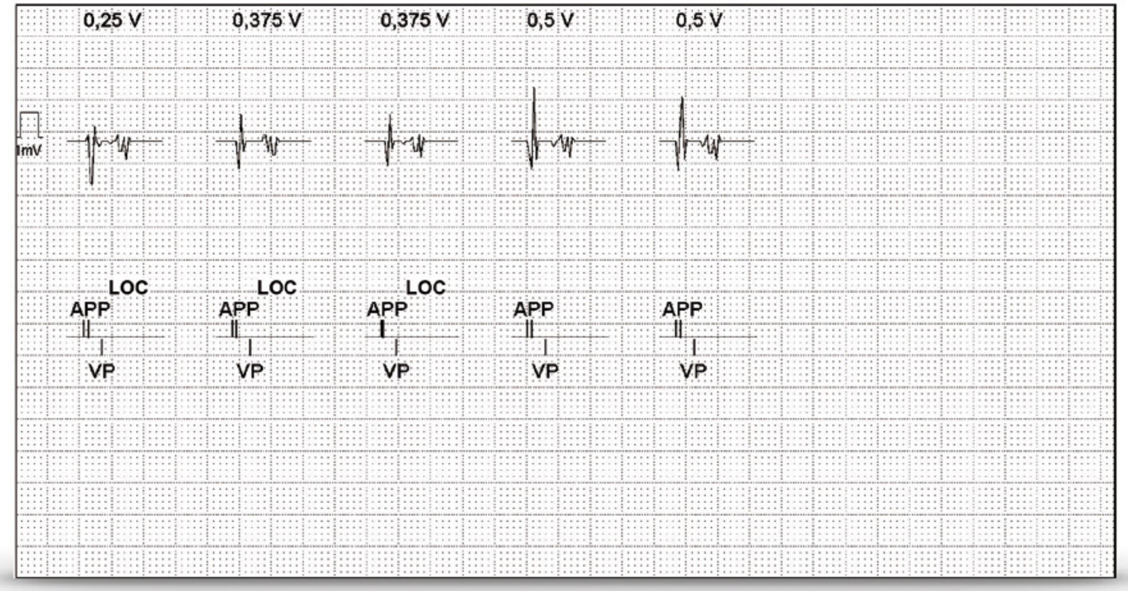
C. there is a cycle-to-cycle control of atrial capture all throughout the day

D. the safety margin varies according to the measured threshold

E. the safety margin is programmable

ANSWER(S)





AP Atrial pacing
VP Ventricular pacing

Tracing 19: functioning of ACap™ Confirm

SUMMARY

TRACING

The ACap™ Confirm graph shows low (<1 Volt) and regular atrial threshold values; the tracing of the last automatic measurement shows an intermittent loss of capture at 0.25 Volts then at 0.375 Volts followed by an effective capture at 0.5 Volts which therefore constitutes the atrial threshold value.

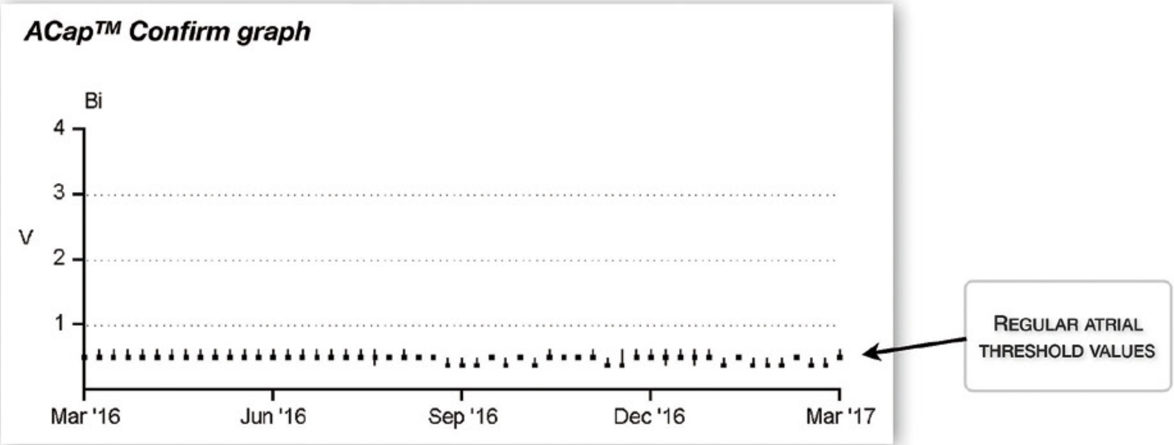
COMMENTS

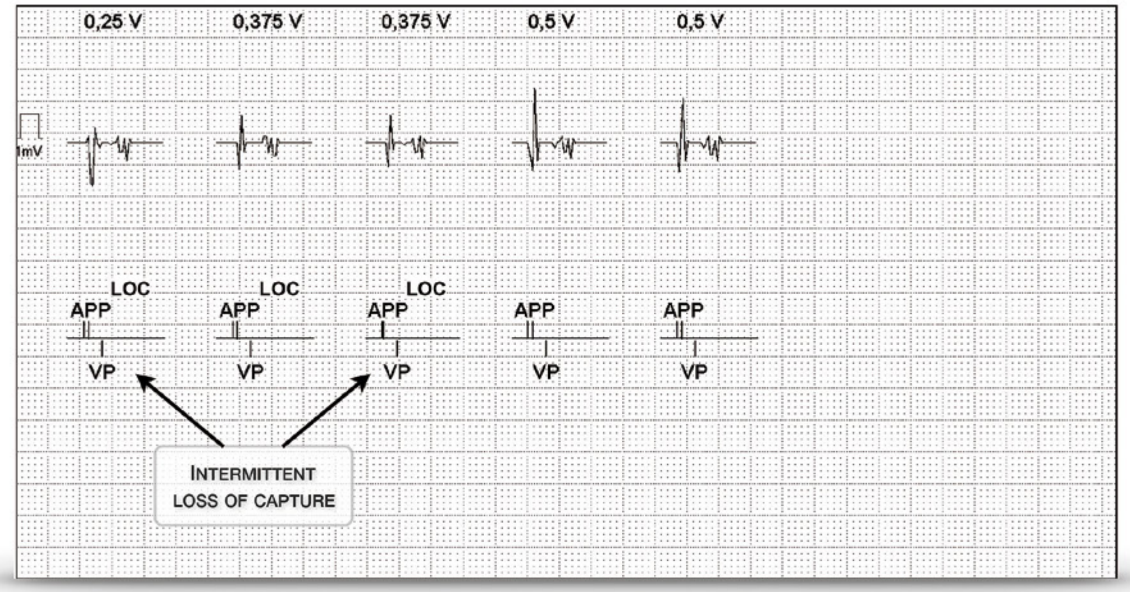
When ACap™ Confirm is programmed to On, the atrial threshold is automatically measured every 8 or 24 hours. The measurement of the atrial threshold is based on the analysis of the morphology of the evoked atrial response. During the threshold measurement, atrial pacing pairs are delivered with a first pulse corresponding to the amplitude tested and a second 5 Volts backup pulse systematically issued 30 ms after the first capture or non-capture. To determine the morphology of the evoked response, a number of points are sampled after the first pulse and after the backup safety pulse. These points are then joined together to define the morphology of the evoked response. Three pairs of atrial pacing are delivered to test the quality of the morphology of the evoked response before each threshold measurement and to determine the morphology corresponding to a loss of capture: a first pair with pacing at 3.875 Volts (effective capture) followed by pacing at 5 Volts (non-capture because occurring during the refractory period of the atrial myocardium); a second pair with pacing at 0 Volt (non-capture) followed by pacing at 5 Volts (effective capture); a third pair with pacing at 0 Volt (non-capture) followed by pacing at 5 Volts (effective capture). The device memorizes the morphology corresponding to a failed capture. The update of the loss of capture model is performed before each threshold measurement during the Setup test. The last acquired loss of capture signal is combined with the last 15 models to compute a rolling average that is continuously updated. The algorithm uses a score to differentiate between the loss of capture morphology and the capture morphology. If the capture score is considerably different from the loss of capture score, then the setup is recommended and the pacing threshold is automatically measured.

The threshold test begins with an amplitude of 0.5 Volts above the value of the last measured threshold; every 2 cycles, the amplitude of the test pulse (systematically followed by a backup 5 Volts pulse) is decreased in steps of 0.25 Volts steps. When 2 losses of capture are observed, the amplitude of the test pulse is then increased in steps of 0.125 Volts every 2 cycles until 2 effective captures are obtained (value corresponding to the pacing threshold).

When the atrial threshold has been measured, the device adjusts the pacing amplitude for the next 8 or 24 hours depending on the programming, with a variable safety margin depending on the threshold.

In order to be able to program ACap™ Confirm, the atrial lead must be bipolar and a good differentiation must be achieved between the morphology corresponding to a loss of capture and the morphology corresponding to an effective capture.


ACap™ Confirm graph
Bi
4
3
2
1
V
Mar '16
Jun '16
Sep '16
Dec '16
Mar '17
Regular atrial threshold values


0,25 V
0,375 V
0,375 V
0,5 V
0,5 V
1mV
LOC
LOC
LOC
APP
APP
APP
APP
APP
VP
VP
VP
VP
VP
Intermittent loss of capture

Patient

77-year-old man implanted with an Accent™ DR pacemaker for carotid sinus syndrome; recording of this tracing the day after implantation.

Quiz

What is the most likely diagnosis?

A. dislodgement of the atrial lead

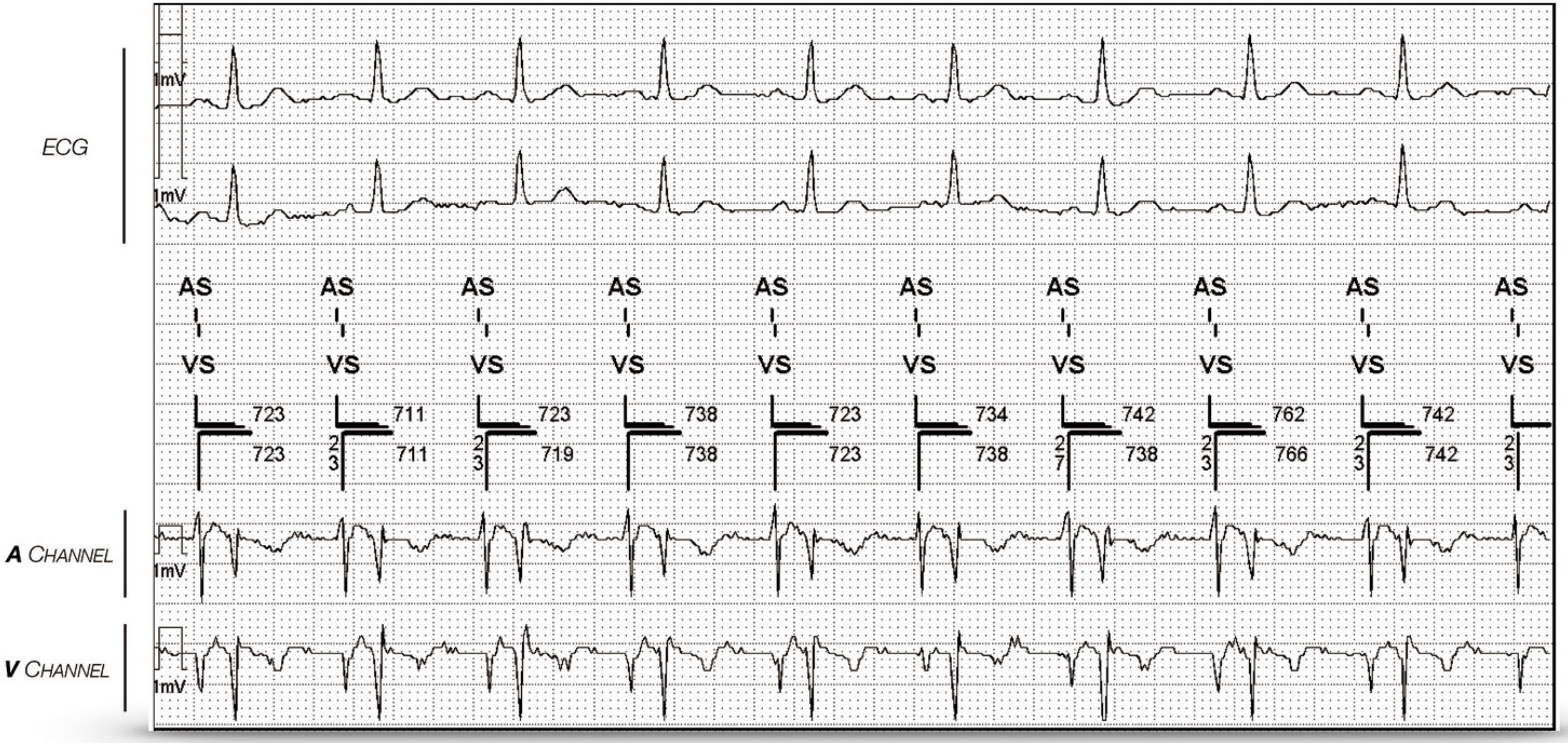
B. dislodgement of the ventricular lead

C. inversion of the 2 leads

D. increase in atrial pacing threshold

E. increase in ventricular pacing threshold

ANSWER(S)



AS Atrial sensing
VS Ventricular pacing

Tracing 20: ventricular lead dislodgement

SUMMARY

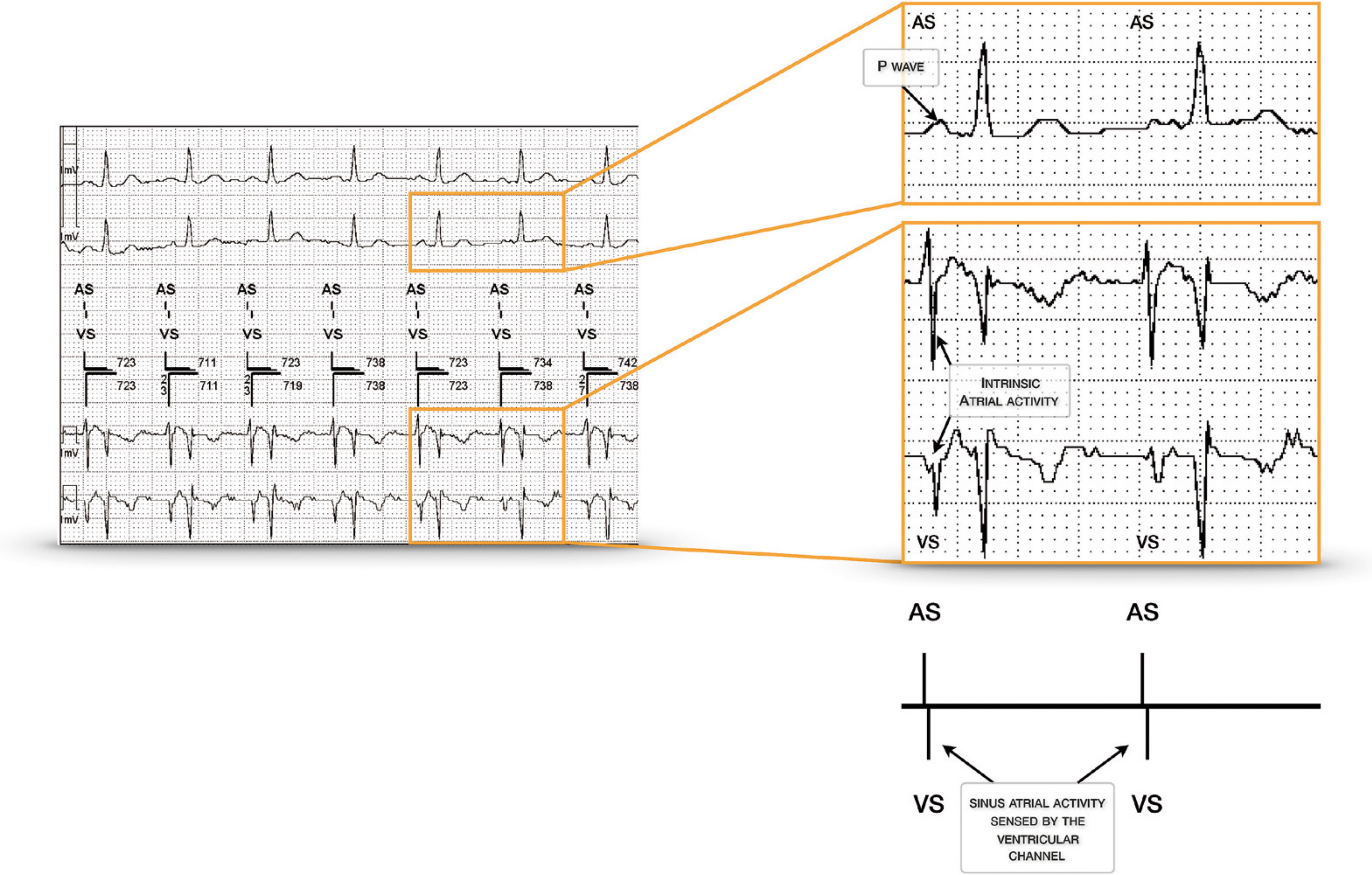
TRACING

The tracing shows a sinus rhythm with a narrow QRS and normal PR interval; sinus atrial activity is sensed both by the atrial channel and the ventricular channel, which suggests a well-positioned atrial lead and a dislodgement of the ventricular lead in the atrial cavity.

COMMENTS

This tracing corresponds to an early dislodgement of the ventricular lead which retreated into the atrial cavity, explaining the simultaneous sensing of sinus activity by the 2 channels. This early dislodgement was related to a poor fixation of the lead at the level of the pacemaker pocket. Repositioning the ventricular lead restored normal operation.

When an abnormal tracing is observed in the immediate aftermath of a dual-chamber pacemaker implantation, the diagnosis of lead dislodgement should be evoked when the functioning of a single lead appears abnormal. The diagnosis of inversion of the 2 leads appears more likely when, clearly, the lead connected to the atrium channel senses and/or paces the ventricle and the lead connected to the ventricular channel senses and/or paces the atrium.


AS
VS
P wave
Intrinsic atrial activity
AS
AS
VS
VS
Sinus atrial activity sensed by the ventricular channel

CHAPTER 3

Sensing and undersensing

Patient

83-year-old man implanted with an Accent™ SR pacemaker for lipothemias due to slow AF; programming in VVI mode; consultation and recording of this tracing.

Quiz

Which answer(s) is(are) true regarding this tracing?

A. failure of ventricular sensing

B. failure of ventricular capture

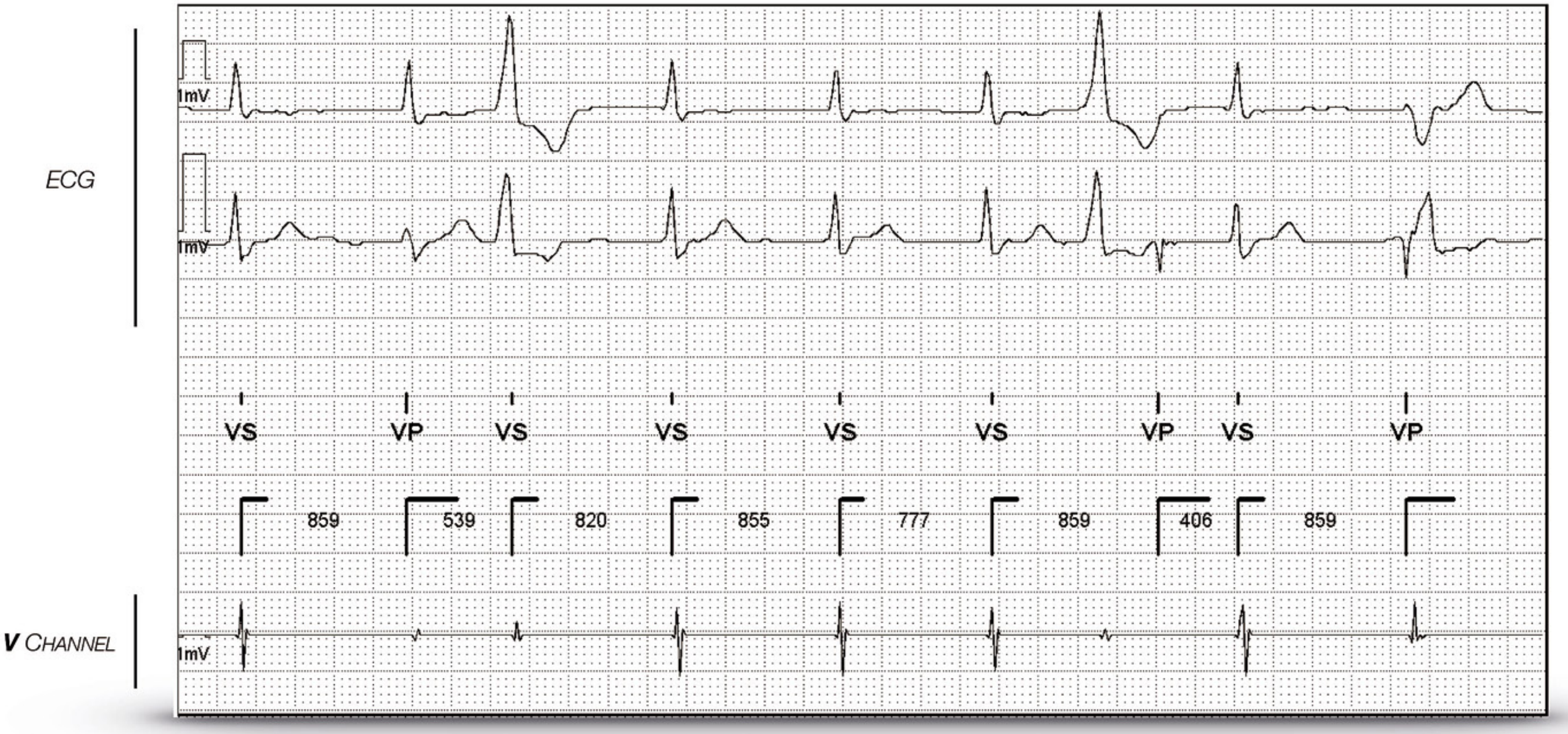
C. ventricular pacing in a vulnerable ventricular period

D. minimum rate programmed at 60 beats/minute

E. minimum rate programmed at 70 beats/minute

ANSWER(S)

Sensing and undersensing



VS Ventricular sensing
VP Ventricular pacing

Tracing 21: ventricular sensing failure

TRACING

The pacemaker is programmed in VVI mode 70 beats/minute; patient in AF; the conducted QRS complexes are seemingly well detected; first premature ventricular contraction well detected; second unsensed premature ventricular contraction; ventricular pacing in vulnerable period without capture because occurring in the absolute refractory period of the ventricular myocardium.

COMMENTS

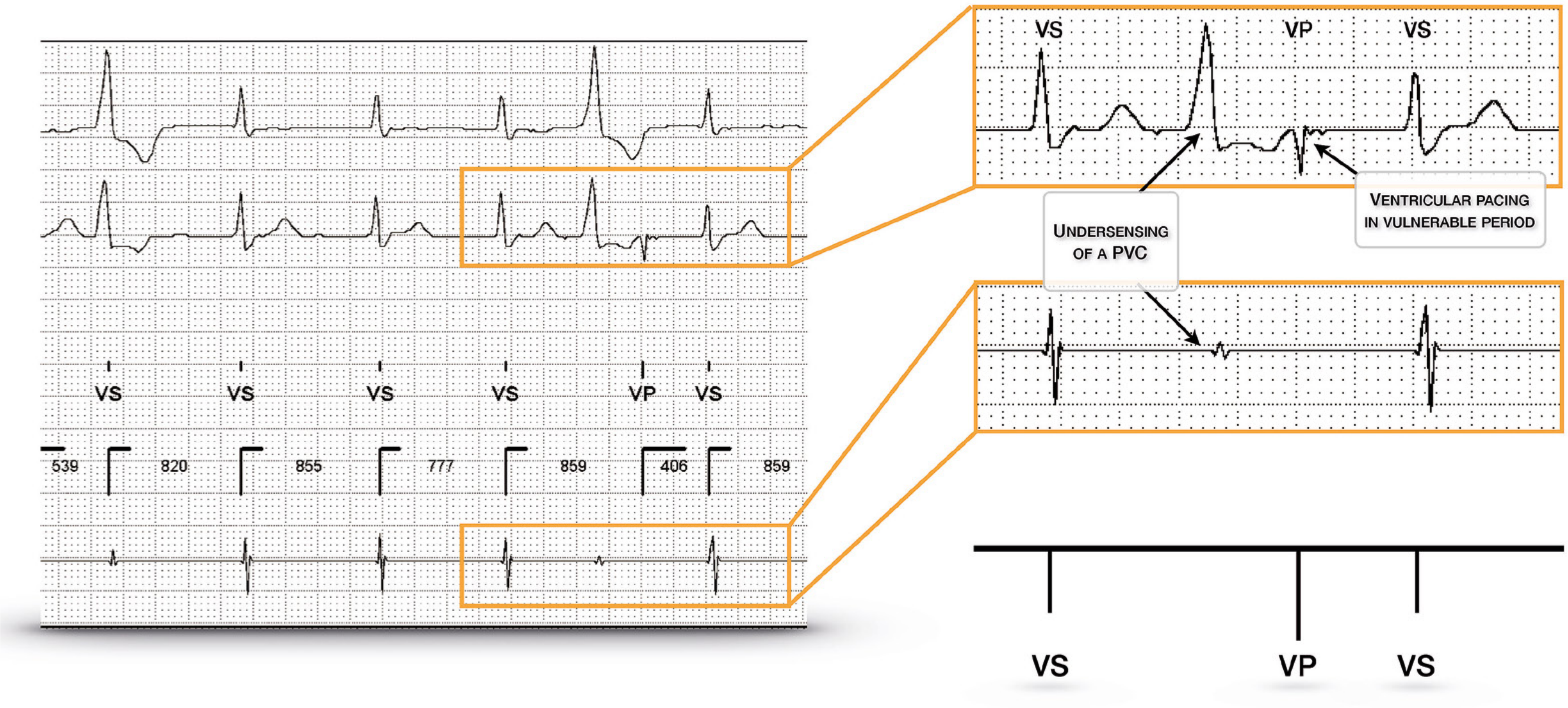
This tracing shows the undersensing of a premature ventricular contraction causing pacing during the vulnerable ventricular period. The depolarization signal of an extrasystole is often fragmented with the slopes of its various components often being slower, thus increasing the risk of undersensing. In the absence of proper sensing, the pacemaker operates in asynchronous mode with no possibility of inhibition by intrinsic ventricular events. There is a low but non-zero theoretical risk of induction of a malignant polymorphic ventricular arrhythmia.

Sensitivity, expressed in millivolt (mV), defines the ability of the pacemaker to properly sense intrinsic cardiac events. Appropriate programming of the sensitivity level should allow the detection of all intrinsic cardiac events occurring in the implanted chamber while not sensing other events (crosstalk with sensing of cardiac signals from the other chamber, myopotentials, interference, etc). The programming of bipolar sensing allows enhancing the specificity of detection relative to unipolar sensing by limiting the risk of sensing extracardiac signals or crosstalk while enabling the programming of high sensitivity values. On the other hand, in unipolar configuration, the risk of crosstalk or sensing extracardiac signals requires the programming of a lower sensitivity level with an increased risk of undersensing.

Traditionally, unlike implantable defibrillators, pacemakers functioned with a fixed and stable sensitivity throughout the cardiac cycle. Nowadays, the various manufacturers offer in their range of devices a fusion between the respective operating platforms of pacemakers and defibrillators. Although the sensing constraints are not the same (critical necessity for a defibrillator to detect and treat very rapid, polymorphic and low-voltage ventricular rhythm disorders), modern pacemakers allow programming an adaptive sensitivity (variable sensitivity level according to the amplitude of the R wave or the sensed P wave). The principle of automatic sensitivity control is to adjust the sensitivity level according to the amplitude of the P wave or the previous R wave and subsequently increase the sensitivity during the cycle. For Abbott™ pacemakers, in bipolar sensing, atrial and ventricular sensitivity can be programmed to automatic (AutoSense™ or SenseAbility™) or fixed. Conversely, the sensitivity is necessarily fixed if sensing is unipolar. When the lead is coded as bipolar, it is possible to program unipolar sensing either between the distal end and the can or between the ring and the can. In the presence of an oversensing or undersensing problem, the choice of the sensing method (fixed or adaptive) will depend primarily on the amplitude of the signals and the variability of the amplitude of these signals.

When an adaptive ventricular sensitivity is programmed, the sensitivity is automatically adjusted to a percentage of the largest value of the 2 components of the previously sensed signal (positive or negative). After sensing of an R wave, at the end of the refractory period, the sensitivity adjustment level begins at a (programmable) percentage of the sensed R wave amplitude (without exceeding 6 mV nor falling below 1 mV), remains the same during the adjustment delay (programmable) after which the sensitivity gradually increases until reaching the programmed sensitivity value. The following parameters are programmable: the post-sensed adjustment level (threshold start between 50 and 100%), the post-paced adjustment level (Auto or between 0.2 and 3 mV), the post-sensed decay delay (between 0 and 220 ms), the post-paced decay delay (Auto or between 0 and 220 ms) and the maximum sensitivity (between 0.2 mV and 2 mV). When the ventricular post-paced decay delay is set to Auto, the device automatically adjusts the delay used after ventricular paced pulse to compensate for the shortening of the QT interval associated with fast pacing rates.

When atrial or ventricular sensing is bipolar, atrial and ventricular sensitivity can be set to automatic (AutoSense™ or SenseAbility™) or fixed. In the presence of an oversensing or undersensing issue, the choice of the sensing method (fixed or adaptive) represents an essential step of the programming and is primarily dependent on the amplitude of the signals and the variability of the amplitude of these signals.


VS
VS
VS
VS
VP
VS
539
820
855
777
859
406
859
VS
VP
VS
Undersensing of a PVC
Ventricular pacing in vulnerable period
VS
VP
VS

Patient

A 69-year-old woman with history of infarction implanted with an Assurity™ + DR pacemaker for complete atrioventricular block; episodes of paroxysmal AF.

Quiz

Which answer(s) is(are) true regarding this tracing?

A. increase in atrial pacing threshold

B. atrial arrhythmia

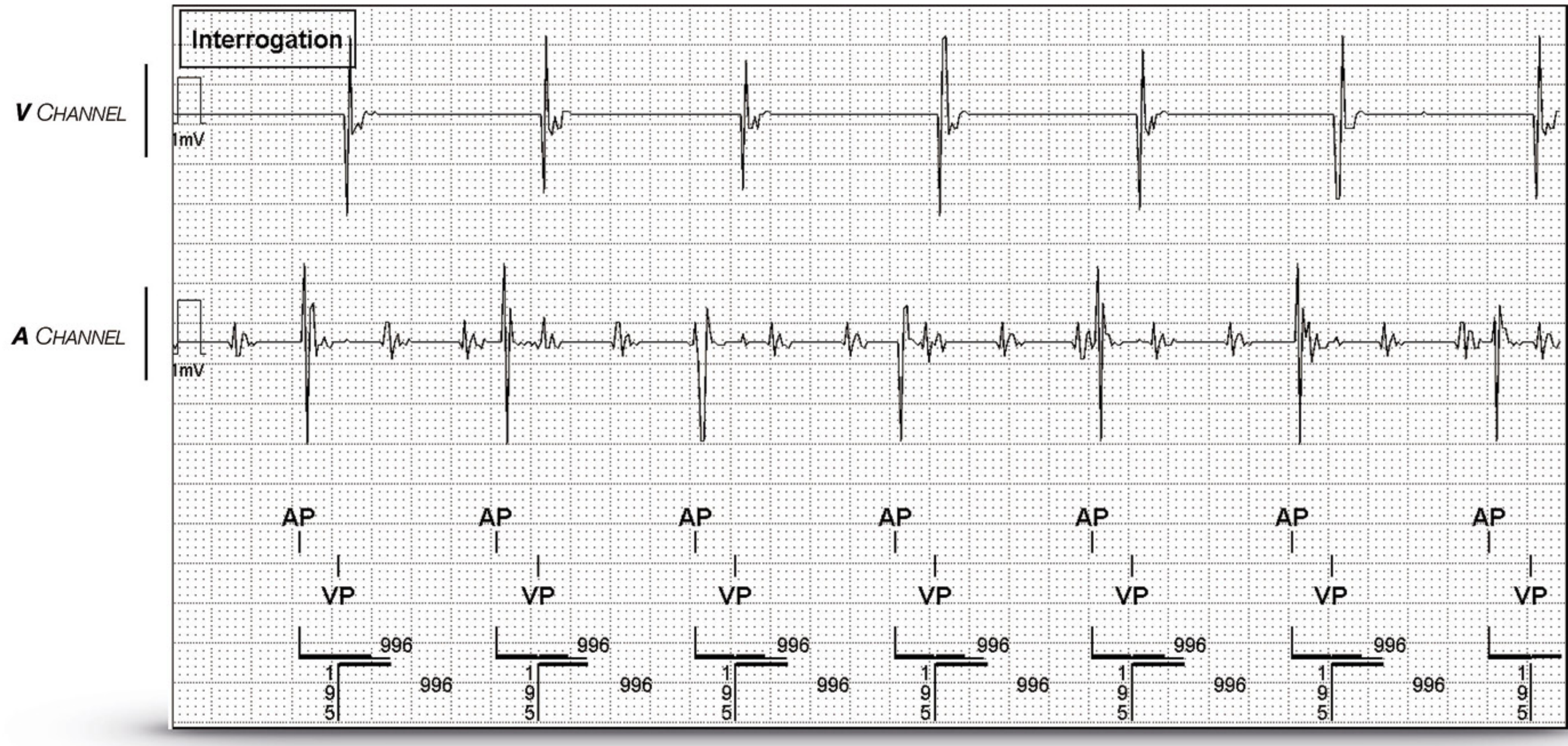
C. failure of atrial sensing

D. ineffective ventricular pacing

E. minimum rate programmed at 60 beats / minute

ANSWER(S)

Sensing and undersensing



AP Atrial pacing
VP Ventricular pacing

Tracing 22: atrial sensing failure

SUMMARY

TRACING

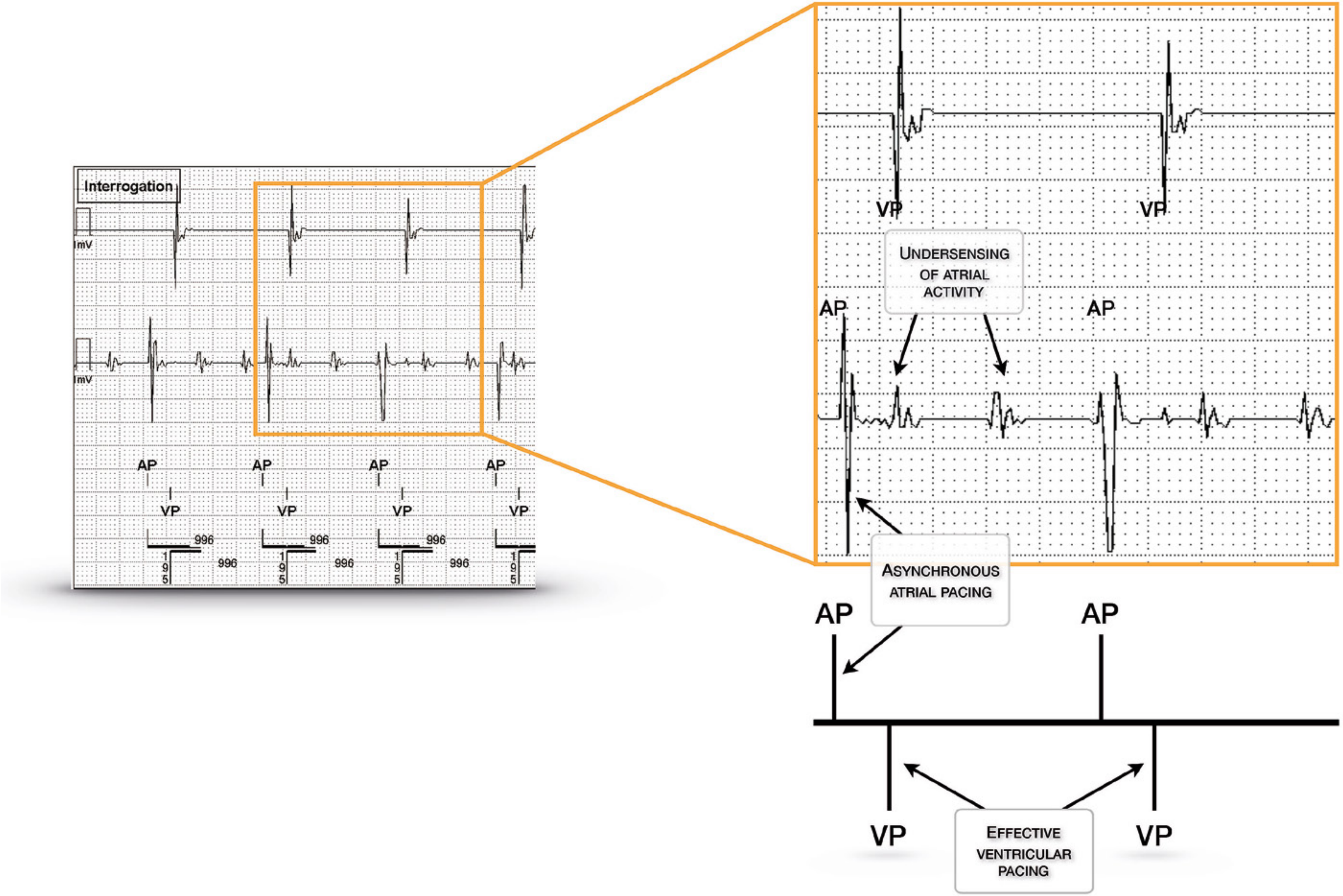
Programming in DDD mode 60 beats/minute; atrial arrhythmia undetected; asynchronous atrial pacing followed by effective ventricular pacing.

COMMENTS

These tracings show atrial undersensing in a patient with AF followed by sinus rhythm. The sensing of the P wave presents certain peculiarities, with the slope of the signal and its amplitude being lower than those of a QRS complex. In addition, the amplitude of the sensed atrial signal can vary depending on the position of the patient and the respiratory cycle. It is therefore important to program a sufficient margin to avoid atrial undersensing problems during exercise which can cause a sudden decrease in the ventricular pacing rate in a patient with atrioventricular block. In addition to the lack of proper P wave monitoring during exercise, atrial undersensing can also have a proarrhythmogenic effect if atrial pacing occurs during a vulnerable atrial period with a risk of induction of atrial arrhythmia. In this patient, undersensing of atrial arrhythmia is responsible for inefficient and unnecessary atrial pacing thereby increasing energy consumption and reducing battery performance. Atrial arrhythmias are not counted thus skewing the data in terms of arrhythmia load rendering the device memory unreliable for assessing the efficacy of antiarrhythmic therapy or for initiating anticoagulant therapy. The second tracing shows an undersensing of sinus activity also leading to the occurrence of asynchronous atrial pacing. In a patient with premature ventricular contractions, as in this tracing, the risk is the occurrence of the undetected extrasystole since falling within the post-atrial ventricular blanking period with potentially-arrhythmogenic ventricular pacing at the end of the programmed AV delay.

When adaptive atrial sensitivity is programmed, after sensing of an atrial signal, the sensitivity adjustment level begins at a programmable percentage of the sensed signal amplitude (not exceeding 3 mV nor falling below 0.3 mV), remains the same during the decay delay (programmable) after which the sensitivity gradually increases until reaching the programmed sensitivity value. The following parameters are programmable: the post-sensed adjustment level (threshold start between 50 and 100%), the post-paced adjustment level (between 0.2 and 3 mV), the post-sensed decay delay (between 0 and 220 ms), the post-paced decay delay (between 0 and 220 ms) and the maximum sensitivity (between 0.2 mV and 1 mV).

Optimizing atrial sensitivity is a crucial phase for programming a dual-chamber pacemaker. It is necessary to program a sufficient margin to integrate the variations in postural and respiratory amplitude. Atrial undersensing skews the assessment of atrial arrhythmia load, can cause unnecessary atrial pacing, can be arrhythmogenic at the atrial stage but also, although more rarely, at the ventricular stage.



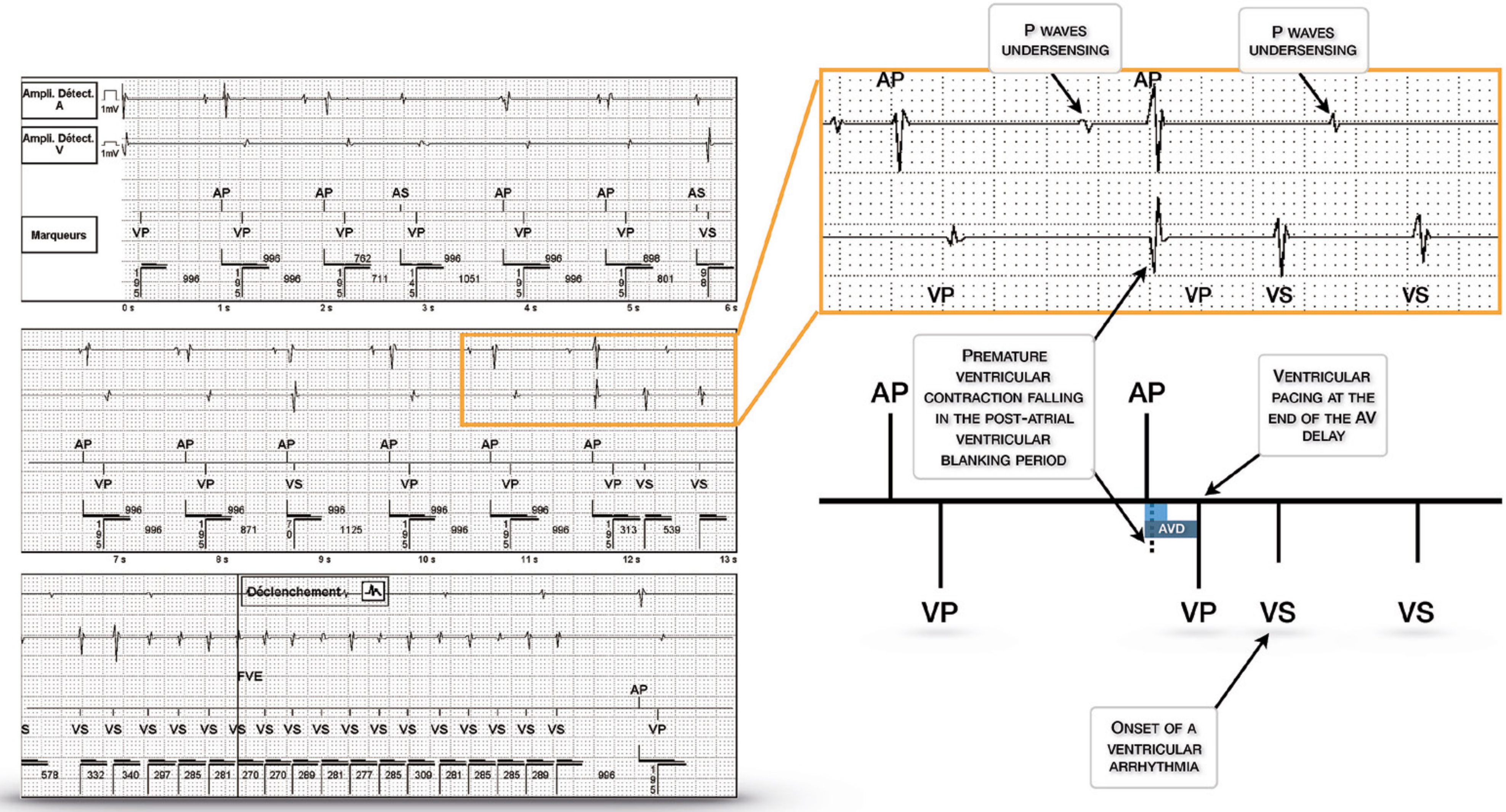
Interrogation
mV
mV
AP
VP
996
1
9
5
Undersensing
of atrial
activity
Asynchronous
atrial pacing
Effective
ventricular
pacing

Tracing 23: atrial sensing failure

SUMMARY

TRACING

Same patient with recording of a HVR episode; sinus rhythm with undersensing of P waves; asynchronous atrial pacing; premature ventricular contraction not sensed because falling in the post-atrial ventricular blanking period; ventricular pacing at the end of the AV delay; beginning of a relatively fast ventricular arrhythmia spontaneously terminating after 5 seconds.


Ampli. Détect. A
Ampli. Détect. V
Marqueurs
Déclenchement
FVE
P WAVES UNDERSENSING
P WAVES UNDERSENSING
PREMATURE VENTRICULAR CONTRACTION FALLING IN THE POST-ATRIAL VENTRICULAR BLANKING PERIOD
VENTRICULAR PACING AT THE END OF THE AV DELAY
AVD
ONSET OF A VENTRICULAR ARRHYTHMIA
AP
AP
VP
VP
VS
VS

CHAPTER 4

Refractory periods

Patient

72-year-old man implanted with an Accent™ DR pacemaker for complete atrioventricular block; recording of this tracing during the consultation.

Quiz

Which answer(s) is(are) true regarding this tracing?

A. the paced atrial AV delay is usually programmed longer than the sensed atrial AV delay

B. the sensed atrial AV delay is usually programmed longer than the paced atrial AV delay

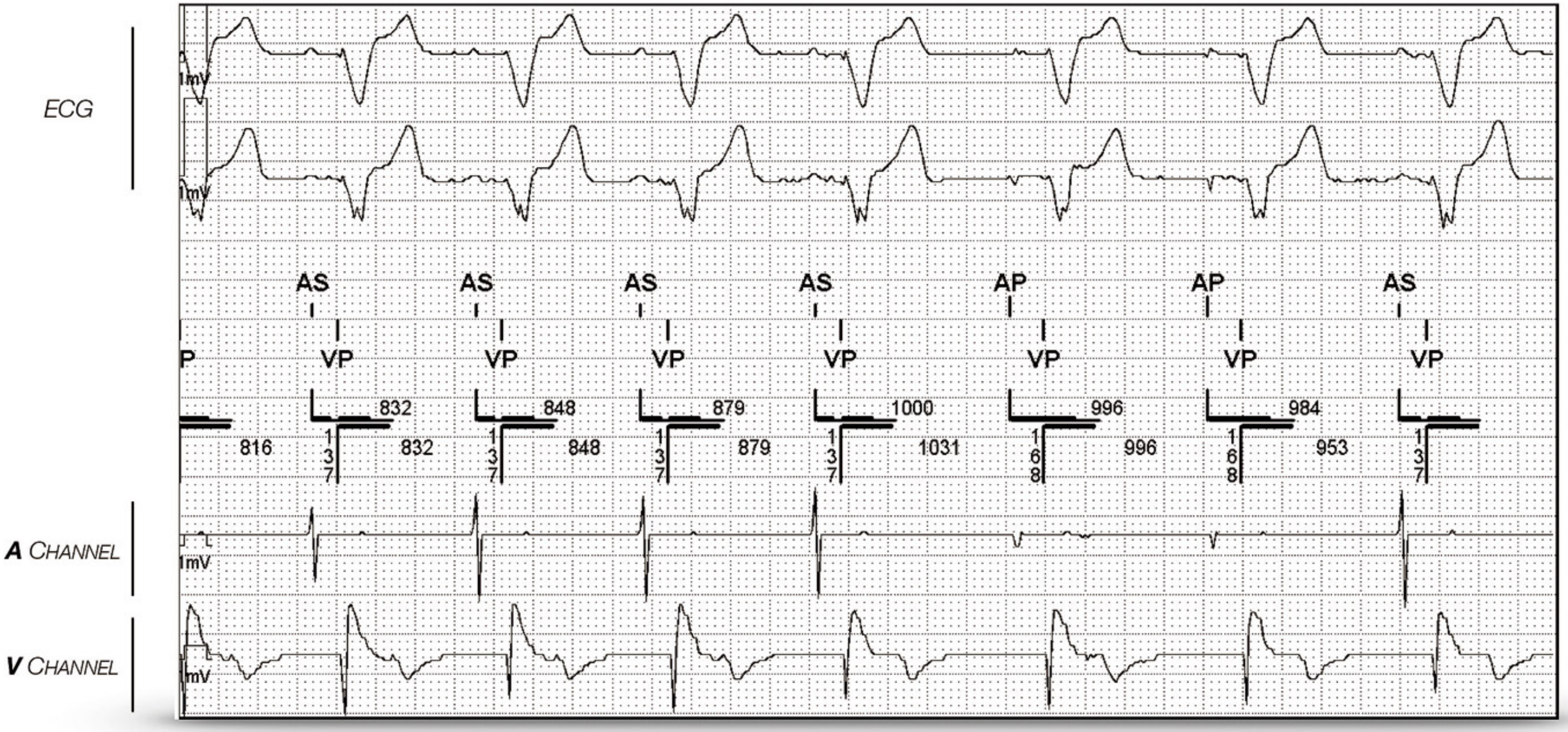
C. failure of atrial sensing

D. ineffective ventricular pacing

E. minimum rate programmed at 60 beats/minute

ANSWER(S)

Refractory periods



AS Atrial sensing
AP Atrial pacing
VP Ventricular pacing

Tracing 24: difference in sensed AV delay and paced AV delay

SUMMARY

TRACING

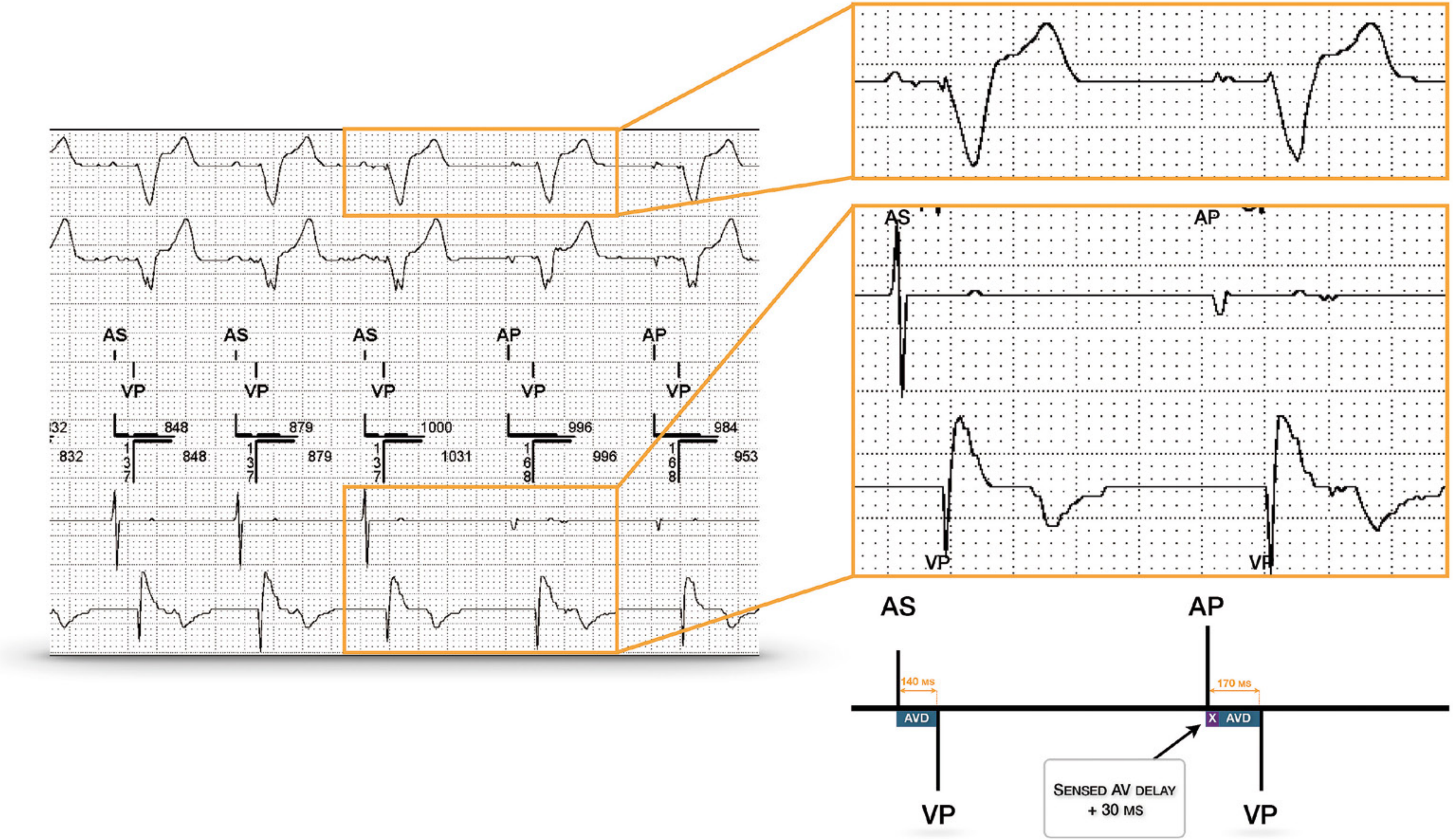
Permanent ventricular pacing; alternation between AS-VP (intrinsic atrium) and AP-VP (paced atrium) cycles; AV delay on paced atrium (170 ms) longer than sensed atrium (140 ms).

COMMENTS

As in this example, the paced atrial AV delay is usually programmed longer than the sensed atrial AV delay for various reasons: the P wave is never sensed at the very beginning of the surface P wave, but rather at the passage of the atrial depolarization wave under the electrode. It is often late comparatively to the beginning of the P wave of the surface ECG. Moreover, when the P wave is paced, the conduction time between the right atrium and the left atrium is prolonged. The difference between sensed and paced AV delays is contingent on the position of the lead in the right atrium: on average 30 ms if the lead is septal, 50 ms if positioned in the appendage, 70 ms if in the upper part of the right atrial edge and 90 ms if low lateral. These values represent averages and it is theoretically necessary to adjust the programming to each individual. These differences are often greater if there is presence of an intra- and/or interatrial conductive disorder. This difference changes little during exercise, with a tendency to shorten under the influence of catecholamines which reduces the interatrial conduction time. If there is a major interatrial conductive disorder, this difference may be greater during exercise. In practice, this value can remain fixed throughout the variation range of the programmed rate.

Physiologically, the PR interval is shortened during exercise, averaging 4 ms for every 10-beat rate acceleration. The adjustment of the AV delay is designed to reproduce this physiological phenomenon, and the same variation is applied to the sensed AV delay and the paced AV delay. The shortened sensed AV delays during exercise increase the sensing window for detecting rapid atrial events by shortening the total atrial refractory period and increasing the rate of appearance of a 2:1 block. The dynamic AV delay adjusts the AV delays linearly as the heart rate increases. It is possible to program 3 levels of AV delay adjustment according to the heart rate: low (shortening of the AV delay by 0.5 ms for a rate increase of 1 beat/minute), medium (shortening of the AV delay by 0.75 ms for a rate increase of 1 beat/minute) and high (shortening of the AV delay by 1.0 ms for a rate increase of 1 beat/minute). The shortening of the AV delay continues until the heart rate reaches the maximum sensor rate or the maximum synchronous rate or if the AV delay value reaches the value of the shortest programmed AV delay.

Depending on the indication for implantation, different algorithms can be programmed to optimize the AV delay. In patients with sinus dysfunction and preserved atrioventricular conduction, the VIP algorithm can reduce the percentage of unnecessary ventricular pacing. In patients with complete atrioventricular block, the QuickOpt™ algorithm can be proposed to optimize the AV delay value. In patients with obstructive hypertrophic cardiomyopathy, negative hysteresis of the AV delay can shorten the AV delay in order to promote permanent ventricular capture and decrease the gradient.


AS
VP
AS
VP
AS
VP
AP
VP
AP
VP
832
848
879
1000
1031
996
984
953
137
168
AS
AP
VP
VP
AS
AP
140 MS
170 MS
AVD
X
AVD
VP
VP
SENSED AV DELAY + 30 MS

Refractory periods

Patient

72-year-old man implanted for a complete atrioventricular block; recording of this tracing during the consultation.

Quiz

Which answer(s) is(are) true regarding the ventricular refractory periods?

A. there is a post-atrial sensing ventricular blanking

B. there is a post-atrial pacing ventricular blanking

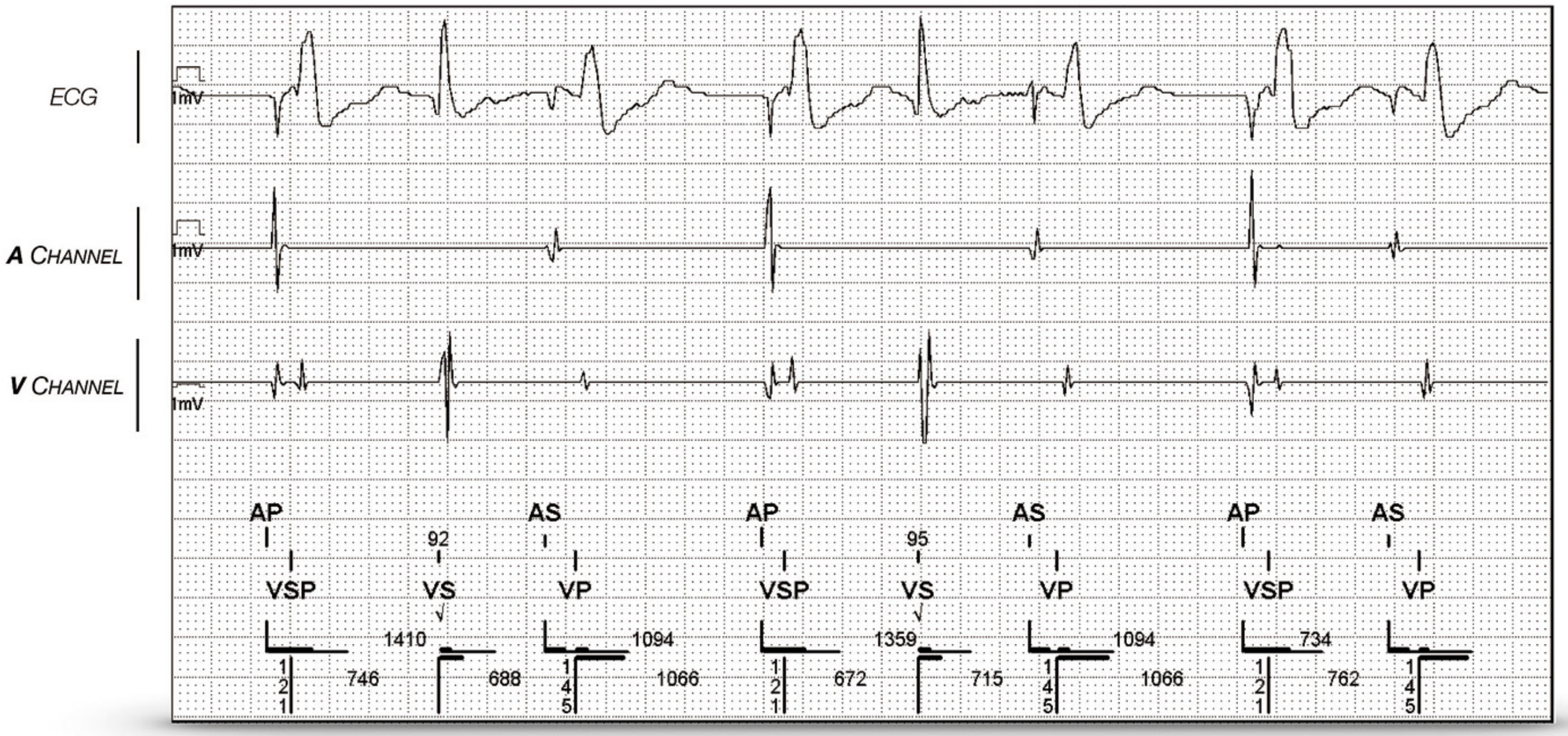
C. there is a post-atrial sensing ventricular safety window

D. there is a post-atrial pacing ventricular safety window

E. ventricular sensing during the safety window causes ventricular pacing 100 ms after the atrial stimulus

ANSWER(S)

Refractory periods



AS Atrial sensing
AP Atrial pacing
VS Ventricular sensing
VP Ventricular pacing
VSP Ventricular pacing after detection in the post-atrial ventricular safety window

Tracing 25: post-atrial ventricular blanking and safety window

SUMMARY

TRACING

Patient with numerous premature ventricular contractions; AP-VSP cycles corresponding to a late premature ventricular contraction detected in the post-atrial ventricular safety window and leading to ventricular pacing 120 ms after the atrial pulse.

COMMENTS

The sensing of atrial activity does not trigger a refractory period in the ventricle, given the limited risk of far-field oversensing (low amplitude of intrinsic atrial signals in the ventricular cavity). However, following an atrial pacing, it is imperative to protect the ventricular cavity, the risk of crosstalk being substantial (pacing in Volts, sensing in mV with a ratio of 1 per 1000).

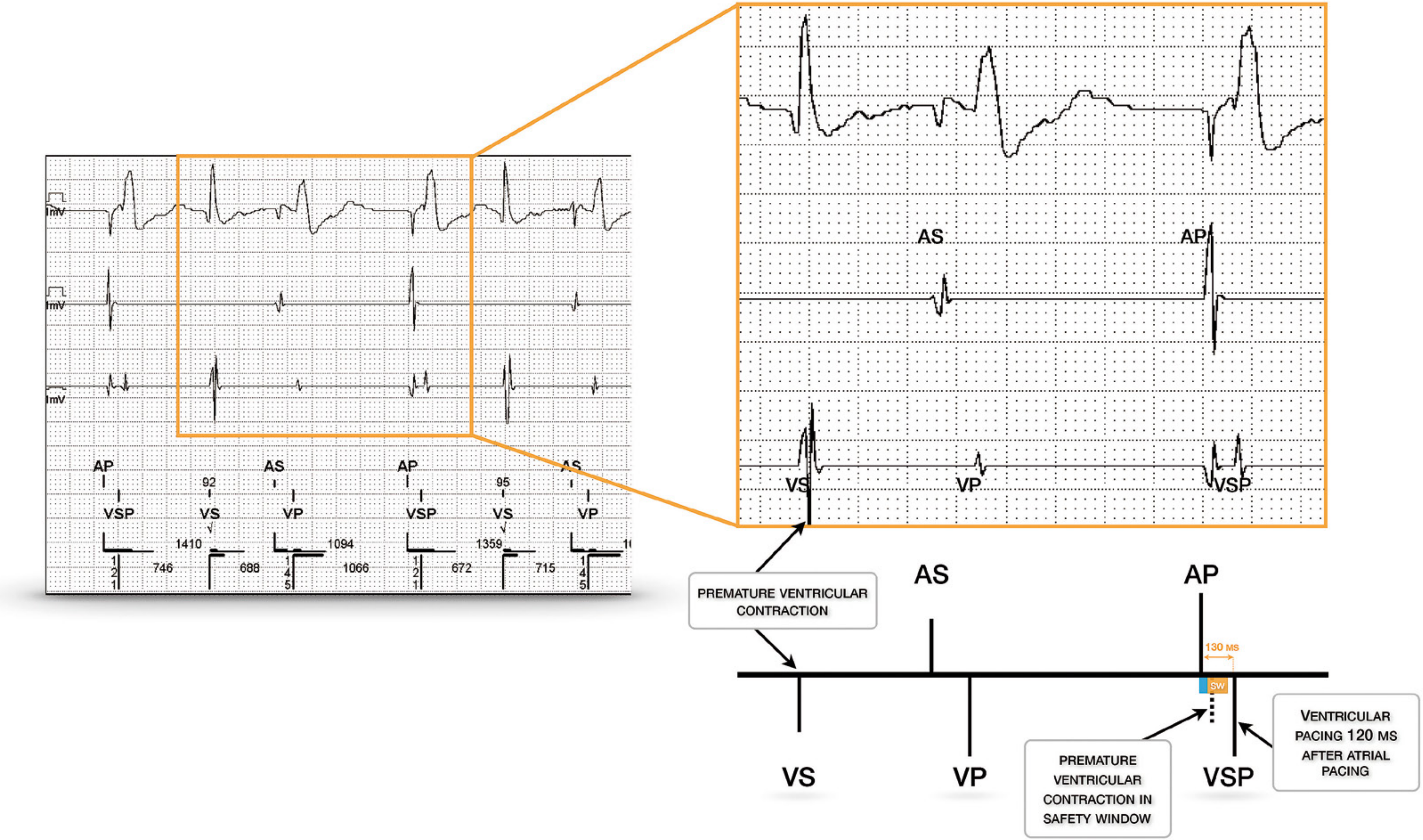
A ventricular blanking period is therefore triggered only after an atrial stimulus. This period is designed to prevent sensing of the atrial stimulus by the ventricular sensing chain which would lead to ventricular inhibition. A ventricular signal occurring during the post-atrial ventricular blanking (premature ventricular contraction, for example) is not sensed and therefore does not inhibit ventricular pacing occurring at the end of the programmed AV delay. This blanking is programmable to AUTO (Accent platform onward, nominal value) or to a fixed value between 12 and 52 ms. When AUTO programming is selected, if a ventricular signal falls during this blanking period, the blanking is automatically prolonged until a signal is no longer sensed or until the limit value of 52 ms.

The safety window is a supplementary ventricular sensing period of the post-atrial ventricular blanking. It is initiated only after atrial pacing and is designed to prevent a premature ventricular contraction due to inappropriate inhibition of ventricular pacing by sensing of the stimulus or of atrial depolarization subsequent to pacing. Ventricular sensing occurring after the post-atrial ventricular blanking but before the end of the safety window is considered non-physiological and causes ventricular pacing at the end of the safety window. If the event sensed in the safety window is the result of crosstalk or oversensed noise, the pacing pulse allows effective ventricular capture at the end of the safety window. If the event sensed in the safety window corresponds to a late premature ventricular contraction or atrioventricular conduction, the pacing at the end of the safety window occurs sufficiently early in the absolute myocardial ventricular refractory period to avoid pacing on at the peak of the T wave.

The safety window can be set to On or Off (nominal value On). If a ventricular signal is sensed in the safety window (begins after the post-atrial ventricular blanking period and ends 64 ms after the atrial stimulus), ventricular pacing is initiated 120 ms after atrial pacing. The short AV delay pattern (120 ms post-atrial pacing) and the VSP marker allow recognizing, on the EGM, when a safety ventricular pacing has been delivered.

When post-atrial ventricular blanking is programmed to Auto, this also has implications for the functioning of the safety window. Any ventricular signal falling during the initial blanking of 12 ms (possible crosstalk) triggers a succession of new re-triggerable 12 ms blanking periods until the sensing stops without exceeding a limit set at 52 ms; if ventricular sensing ends before this 52 ms limit, the crosstalk window is not required and is canceled (ventricular sensing occurring after the 52 ms limit and before the end of AV delay inhibits ventricular pacing); if ventricular sensing continues beyond this 52 ms limit, the safety window lasts 52 to 64 ms after atrial pacing; ventricular sensing in this window leads to ventricular pacing 120 ms after the atrial stimulus.

Atrial sensing does not trigger refractory periods in the ventricular channel. Conversely, atrial pacing triggers ventricular blanking followed by a relatively short safety window, starting at the end of the blanking period and ending at 64 ms after the atrial stimulus. Any ventricular sensing in this window triggers ventricular pacing 120 ms after the atrial stimulus.


mV
AP
VSP
92
VS
AS
VP
AP
VSP
95
VS
AS
VP
1410
1094
1359
746
688
1066
672
715
AS
AP
VS
VP
VSP
PREMATURE VENTRICULAR CONTRACTION
AS
AP
130 MS
SW
VS
VP
VSP
PREMATURE VENTRICULAR CONTRACTION IN SAFETY WINDOW
VENTRICULAR PACING 120 MS AFTER ATRIAL PACING

Patient

61-year-old man implanted with an Accent™ DR dual-chamber pacemaker for complete atrioventricular block; consults for palpitations; during interrogation of the pacemaker, evidence of tachycardia.

Quiz

Which answer(s) is(are) true regarding this tracing?

A. this is a PMT

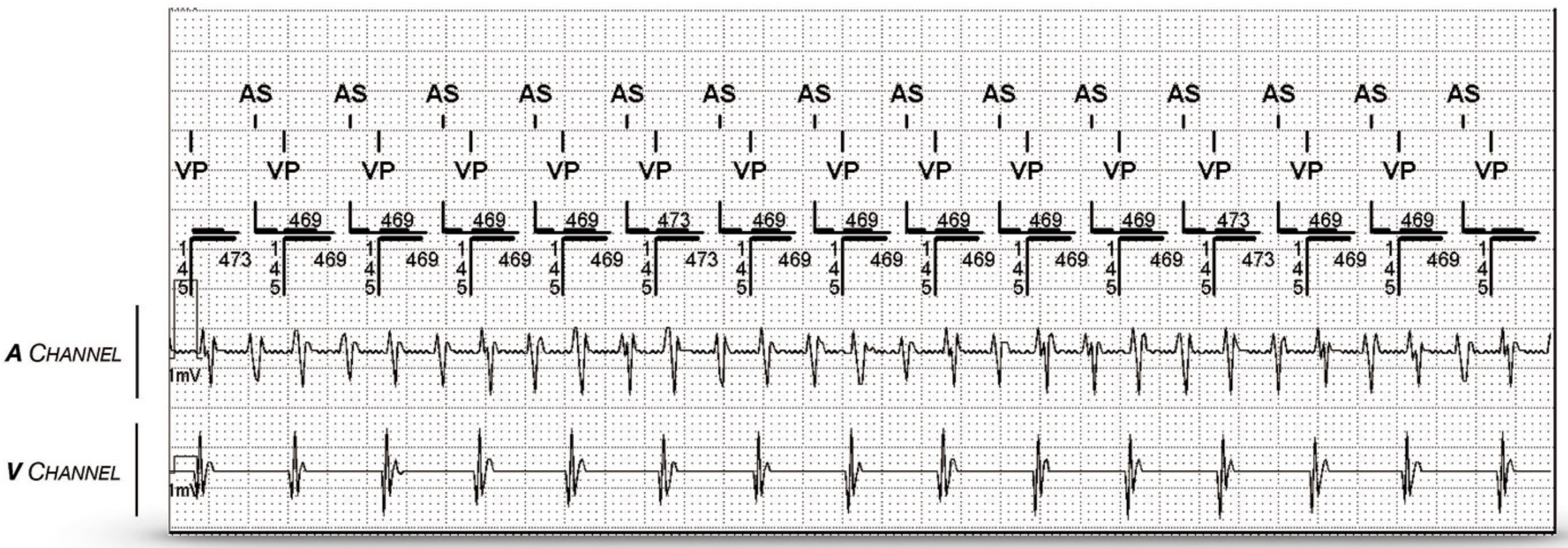
B. this is a sinus tachycardia

C. this is an atrial sensing failure (low-amplitude signals)

D. this is a 2:1 flutter

E. the pacemaker has switched to DDI as fallback mode

ANSWER(S)



AS Atrial sensing
VP Ventricular pacing

Tracing 26: post-ventricular atrial blanking and 2:1 flutter

SUMMARY

TRACING

The atrial EGM reveals the presence of atrial tachycardia (flutter) with regular, monomorphic atrial cycles (true intervals 235 ms); one out of every two signals is sensed by the atrial channel, the second signal falling within the post-ventricular atrial blanking (bold line); rapid ventricular pacing at 130 beats/minute, one out of two atrial cycles being classified as AS and thus triggering an AV delay; absence of fallback.

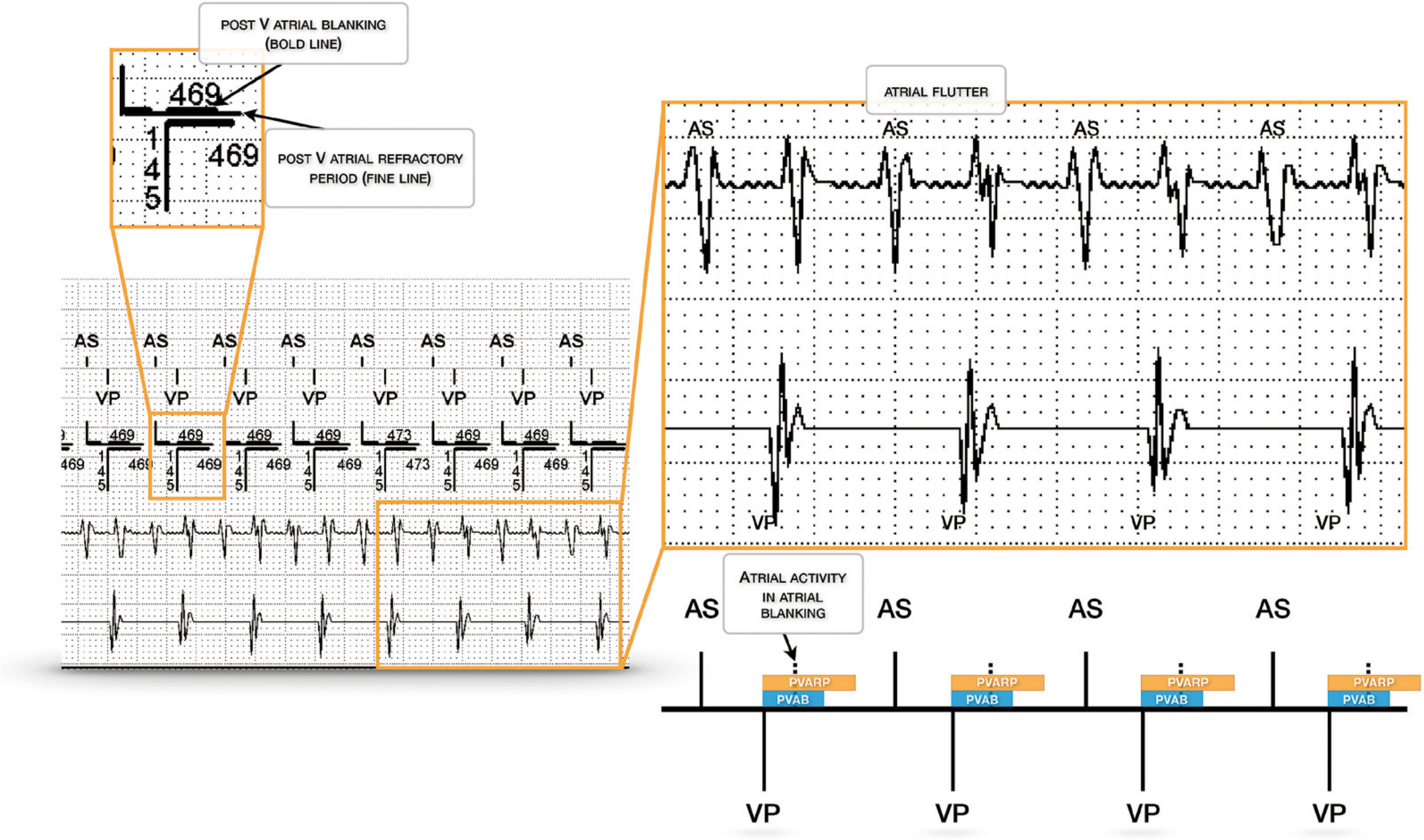
COMMENTS

This tracing shows the limitations of the programming of an overly prolonged post-ventricular atrial blanking period. Failure to sense one out of two atrial signals during a flutter episode leads to the occurrence of poorly-tolerated paced tachycardia in this pacemaker-dependent patient. Reducing its value allows the diagnosis of atrial arrhythmia and rapid mode switching. To avoid crosstalk while maintaining the ability to properly sense atrial arrhythmias, the programming can teeter on a balance between blanking periods and atrial sensitivity.

Post-ventricular atrial blanking (PVAB) is an absolute refractory period applied in the atrium after ventricular sensing and pacing. Its duration can be viewed on the tracing by a bold line following ventricular pacing. Its purpose is to avoid the sensing of the ventricular pacing artifact and the depolarization of the intrinsic or paced ventricle by the atrial channel. The atrial events occurring during this absolute refractory period are not sensed and are therefore not taken into account for the counting of atrial arrhythmias (calculation of the filtered atrial rate). The duration of the atrial blanking is programmable between 60 to 250 ms with a nominal value of 150 ms.

The post-ventricular atrial refractory period (PVARP) is a relative refractory period that follows the PVAB. Its main function is to prevent the occurrence of pacemaker-mediated tachycardia by classifying retrograde atrial conduction as refractory (AR on the marker chain). To avoid recycling ventricular pacing due to retrograde atrial conduction, the PVARP must theoretically be programmed to a value greater than the patient's retrograde ventriculoatrial conduction time. The mean value of the retrograde conduction time is between 220 and 280 ms depending on the patients, although can sometimes be even longer with the need to extend the PVARP. A PVARP programmed too long can, however, induce the appearance of a 2:1 block during exercise at quite low intrinsic rates when the pacemaker is functioning in atrial tracking mode (DDD or VDD). The PVARP is programmable between 125 and 500 ms (nominal value 275 ms). The programming of a dynamic PVARP enables adjusting the value of the PVARP according to the heart rate thereby distancing the 2:1 point. This setting can be set to Off, Low, Medium, High. The PVARP is shortened linearly in order to reach a target atrial sensing window which is even more extensive if the parameter is set to High. It is also necessary to program the shortest PVARP (programmable between 125 and 475 ms, nominal value 175 ms).

The absence of fallback on an AF episode is most often related to the undersensing of low-amplitude cycles. The absence of fallback on an atrial flutter episode is most often related to the programming of an overly long post-ventricular atrial blanking, with every second atrial activity not being sensed as is the case in this example.

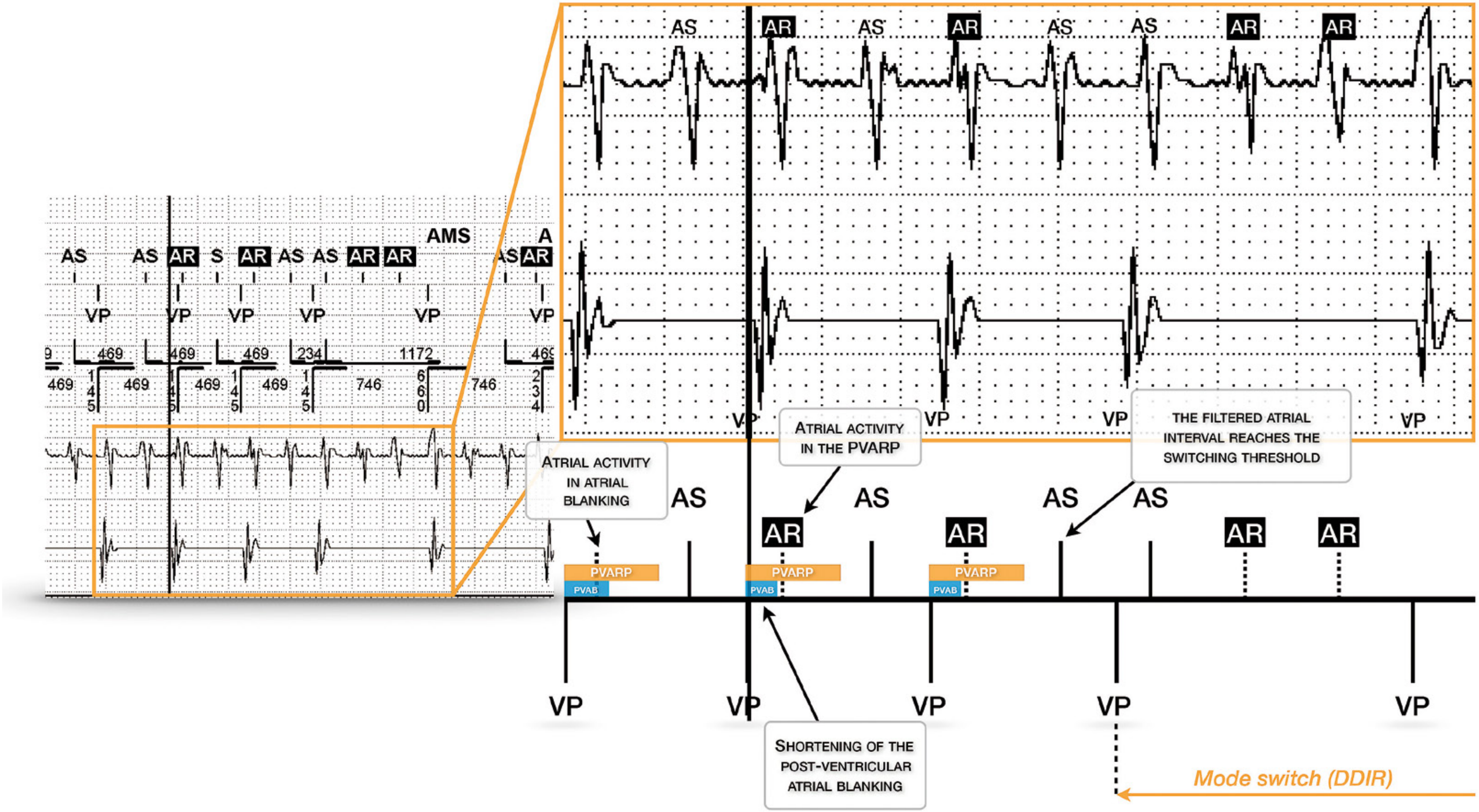

POST V ATRIAL BLANKING (BOLD LINE)
POST V ATRIAL REFRACTORY PERIOD (FINE LINE)
ATRIAL FLUTTER
AS
VP
469
473
145
ATRIAL ACTIVITY IN ATRIAL BLANKING
PVARP
PVAB

Tracing 27: post-ventricular atrial blanking and 2:1 flutter

SUMMARY

TRACING

Continuation of the tachycardia; modification of the programming with shortening of the post-ventricular atrial blanking (vertical line); the second atrial signal is now sensed in the PVARP (AR); the filtered atrial interval quickly reaches the switching threshold; DDIR mode and progressive deceleration of the ventricular pacing rate toward the sensor rate.


AMS
Atrial activity in atrial blanking
Atrial activity in the PVARP
The filtered atrial interval reaches the switching threshold
Shortening of the post-ventricular atrial blanking
PVARP
PVAB
AS
AR
VP
Mode switch (DDIR)

SUMMARY

Patient

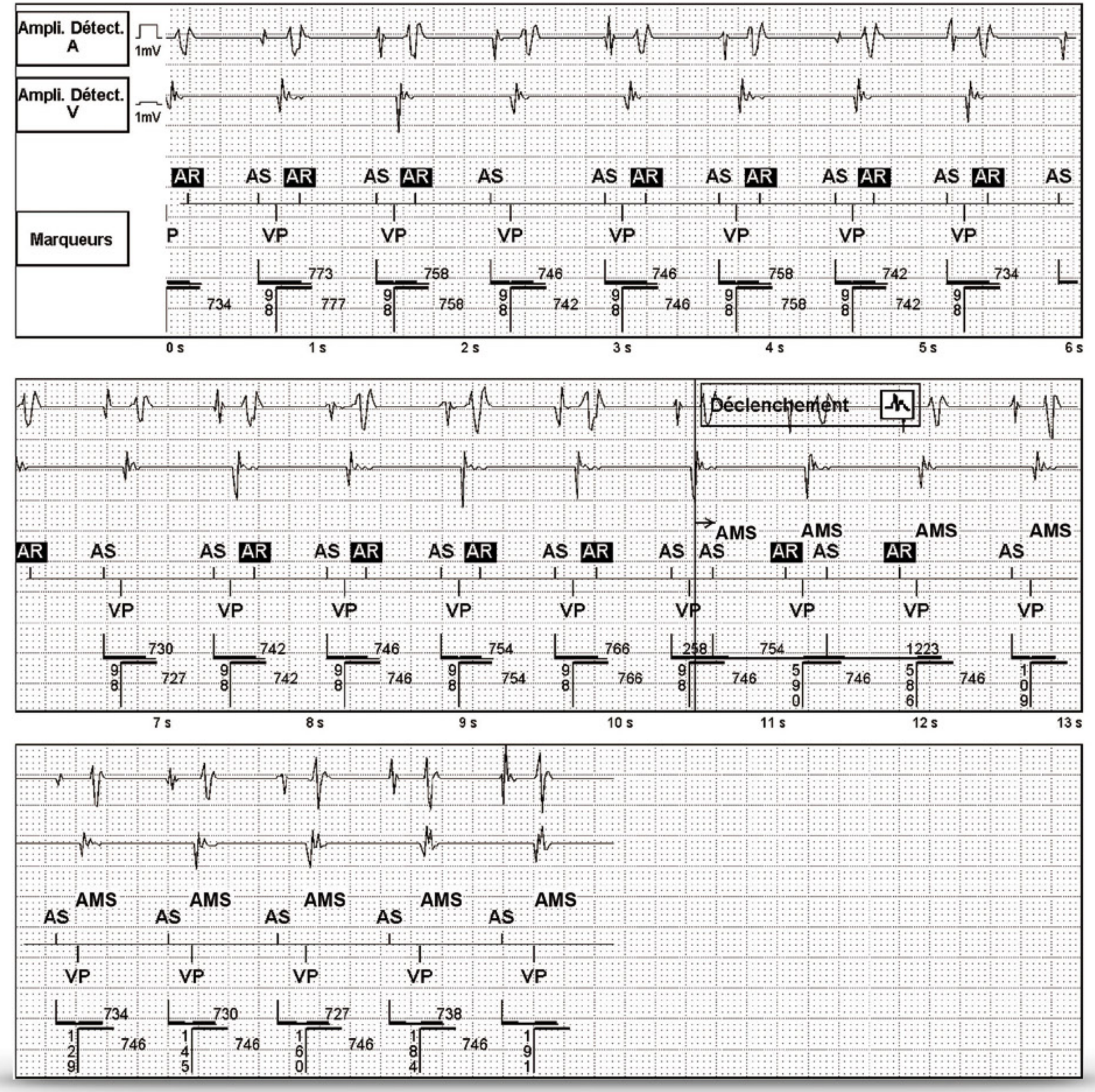
74-year-old woman, implanted with an Assurity MR™ dual-chamber pacemaker for complete atrioventricular block; during the interrogation, highlighting of an episode of automatic mode switching (AMS) stored in the device memory.

Quiz

Which answer(s) is(are) true regarding this tracing?

A. switching occurs as a result of atrial bigeminism
B. switching occurs as a result of crosstalk
C. switching occurs as a result of an atrial flutter
D. switching occurs as a result of an AF
E. switching occurs as a result of noise oversensing

ANSWER(S)



AS Atrial sensing
AR Atrial sensing in PVARP
VP Ventricular pacing

Tracing 28: post-ventricular atrial blanking and crosstalk

SUMMARY

TRACING

At the beginning of the tracing, atrial sensing (AS) and ventricular pacing (VP); after each ventricular pacing, presence of a signal sensed by the atrial channel with a fixed coupling; probable far-field R-wave oversensing; the oversensed signal falls in the PVARP (AR) and therefore does not trigger an AV delay but is counted for the assessment of the filtered atrial rate; this succession of cycles with far-field R-wave oversensing leads to mode switching (AMS) in DDIR mode; loss of atrioventricular synchrony (DDIR mode, no ventricular synchrony on sensed P wave).

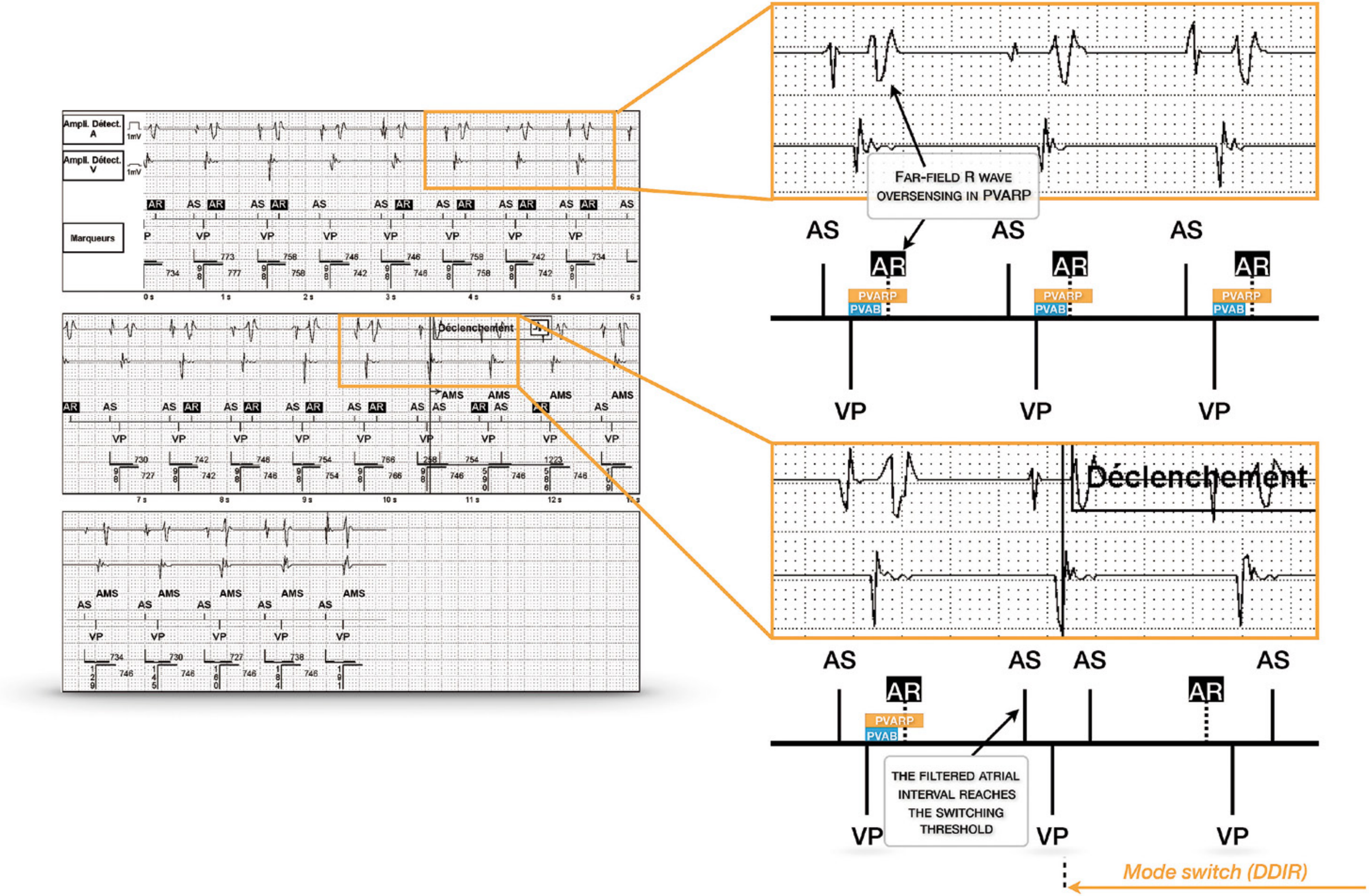
COMMENTS

Following ventricular pacing, atrial sensing is inhibited for the duration of the post-ventricular atrial blanking period in order to avoid far-field R-wave oversensing. This blanking must be programmed sufficiently long to avoid sensing of the stimulus but also to avoid sensing of ventricular depolarization by the atrial channel. It should not be programmed too long in order to avoid undersensing of a possible episode of atrial arrhythmia as on the previous tracing. Following this blanking, the PVARP begins, where a signal is sensed and is counted for the atrial arrhythmia diagnosis but does not trigger an AV delay to avoid the risk of PMT.

In this patient, ventricular depolarization is systematically oversensed (in the PVARP) by the atrial channel. Repetition of these cycles leads to mode switching. The Fallback function on Abbott™ devices is based on an analysis of the filtered atrial rate interval. A short cycle decrements this interval by 39 ms while a long cycle increments the interval by 23 ms. The succession of atrial cycles presented by this patient (short cycle, long cycle) results in a systematic 13 ms incrementation of the filtered atrial rate interval. The latter progressively reaches the threshold for mode switching which results in the loss of atrioventricular synchrony.

In this patient, it is possible to prolong post-ventricular atrial blanking so as to prevent this signal from being counted in the computation of the filtered atrial rate interval or to reduce atrial sensitivity. These 2 options can be accompanied by an altered sensing of AF (primarily for the reduction in atrial sensitivity) or 2:1 atrial flutter (primarily for prolonging atrial blanking).

Setting a post-ventricular atrial blanking that is too long exposes the patient to the risk of non-detection of atrial flutter/tachycardia. Conversely, when the blanking is too short, the risk of far-field R-wave oversensing is increased.



Ampli. Détect. A
Ampli. Détect. V
Marqueurs
Déclenchement
AS
AR
VP
AMS
PVARP
PVAB
FAR-FIELD R WAVE OVERSENSING IN PVARP
THE FILTERED ATRIAL INTERVAL REACHES THE SWITCHING THRESHOLD
Mode switch (DDIR)

Patient

68-year-old man, implanted with an Assurity™ + DR dual-chamber pacemaker for paroxysmal syncopal complete atrioventricular block; during the interrogation, highlighting of a PMT episode stored in the device memory.

Quiz

Which answer(s) is(are) true regarding this tracing?

A. the maximum synchronous rate is programmed at 120 beats/minute

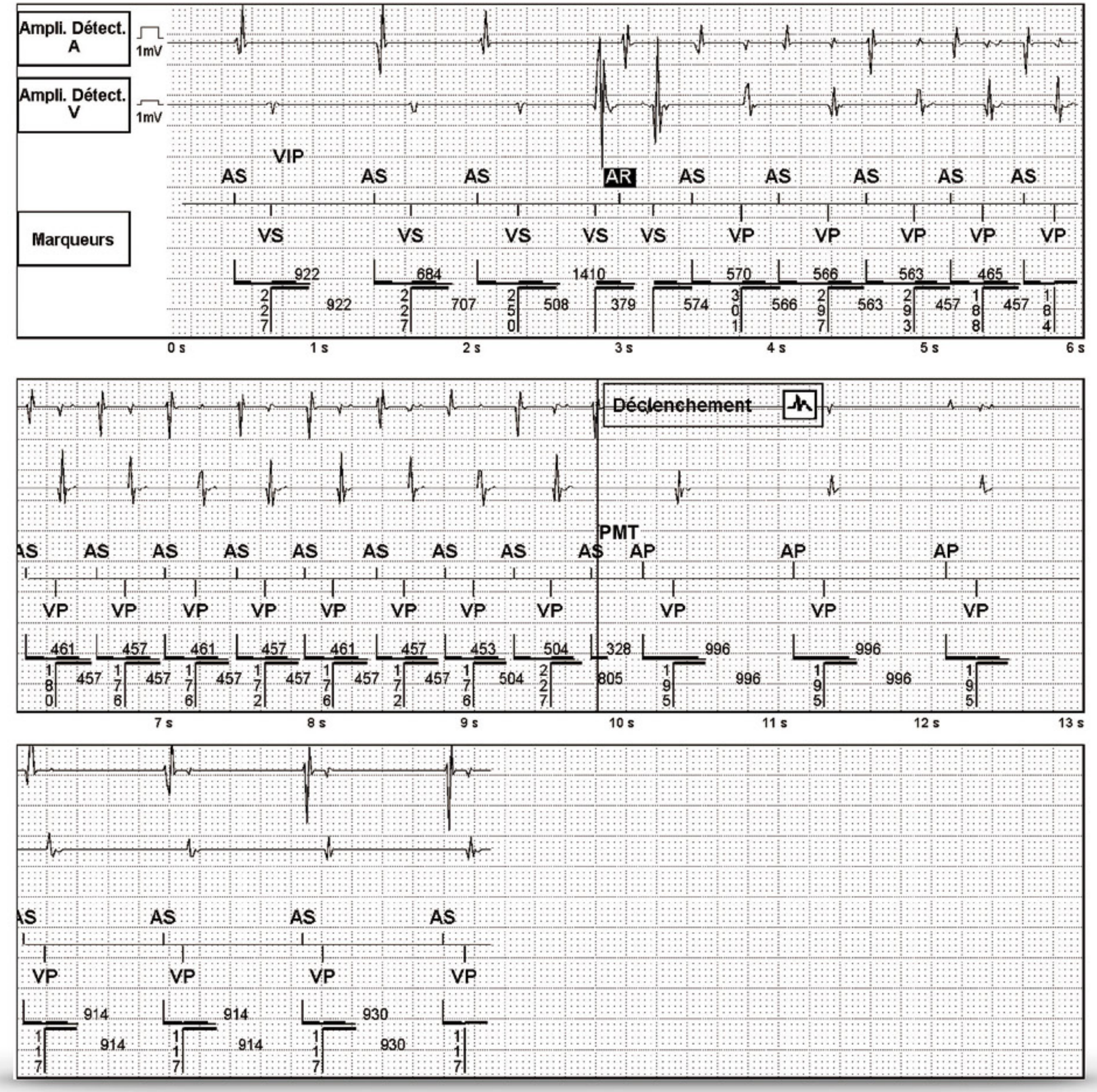
B. the PMT begins following the occurrence of a doublet of premature ventricular contractions

C. VIP programming promotes the occurrence of retrograde conduction

D. to confirm the presence of the PMT, the device modifies the AV delay for one cycle

E. to terminate the PMT, the device extends the PVARP for one cycle

ANSWER(S)



AS Atrial sensing
AR Atrial sensing in PVARP
VP Ventricular pacing

Tracing 29: pacemaker-mediated tachycardia

TRACING

Initially, the VIP algorithm allows intrinsic atrioventricular conduction (AP-VS cycles with AP-VS interval time greater than the programmed AV delay); occurrence of a doublet of premature ventricular contractions with retrograde conduction; on the first cycle, the atrial signal falls within the PVARP (AR); on the second cycle, the retrograde atrial activity is classified as AS and thus triggers a prolonged delay (VIP) which favors the occurrence of a new retrograde conduction; onset of a PMT; over 3 cycles the AV delay is very long (VIP programmed for 3 cycles); maintenance of the PMT followed by return to the programmed AV delay (slightly prolonged so as not to exceed the maximum synchronous rate which is programmed at 130 beats/minute); after 8 consecutive VP-AS cycles greater than 110 beats/min without significant change in the VP-AS interval, suspicion of PMT; prolongation of the AV delay by 50 ms for one cycle (from 170 to 220 ms); on the next cycle, the VP-AS interval remains stable (50 ms prolongation of the AS-AS interval): diagnosis of PMT by the device; the following AS cycle does not trigger an AV delay; atrial pacing 330 ms after this non-followed AS, then ventricular pacing; termination of the PMT.

COMMENTS

This tracing shows a PMT episode diagnosed, processed and stored in memory by the device. The tachycardia begins in a patient presenting retrograde conduction, premature ventricular contractions which dissociate atrial and ventricular activation, and in whom the VIP has been programmed with a temporary extension of the AV delay. The onset of a pacemaker-mediated tachycardia (PMT) involves the programming of an atrial tracking mode (DDD or VDD), the permeability of retrograde conduction, and a momentary or permanent loss of atrioventricular synchrony. Indeed, while ventricular activity is properly synchronized with that of the atrium, retrograde conduction is blocked. Maintenance of the PMT results from the sensing of a retrograde P wave outside of the refractory periods which causes the triggering of an often prolonged AV delay, which again favors retrograde conduction after ventricular pacing. A PMT is therefore a repetitive sequence in which the pacemaker responds to each retrograde P wave by pacing the ventricle at a high rate which in turn generates a retrograde P wave.

The cycle hence repeats itself indefinitely unless there is appearance of a retrograde block or the intervention of a specific algorithm. A prolonged PMT may be poorly tolerated with symptoms ranging from simple feeling of discomfort/uneasiness or palpitations up to cardiac decompensation in patients with an underlying heart disease. The rate of a PMT is contingent on the retrograde conduction time, the programmed maximum rate, and the current AV delay.

This tracing shows the specific features of Abbott™ devices in PMT management:

1) three settings are possible for the diagnosis and termination of PMTs:

- Off, no PMT detected;
- Passive: the PMTs are detected and counted in the diagnostics but the termination algorithm is not used;
- Atrial Pacing: the PMTs are detected and the specific termination algorithm is used;

2) it is possible to program a PMT detection rate which determines the low rate limit from which a tachycardia may correspond to a PMT; this parameter can be set between 90 and 180 beats/minute and cannot exceed the value of the maximum synchronous rate;

The following events can favor AV dissociation, retrograde conduction, and the onset of a PMT: premature ventricular contraction (the most common cause), premature atrial contraction with prolonged AV delay to maintain the programmed maximum heart rate, AV delay programmed too long, external or myopotential interference sensed by the atrial chain, lack of atrial capture, no extension of PVARP after removal of a magnet or at the end of measurement of the atrial threshold, application and removal of a magnet, programming of the VDD mode in a patient with sinus rhythm slower than the programmed minimum rate.

3) the device suspects the presence of a PMT after 8 consecutive VP-AS cycles with AS-AS intervals higher than the PMT detection rate and with stable VP-AS intervals (standard deviation ± 16 ms);

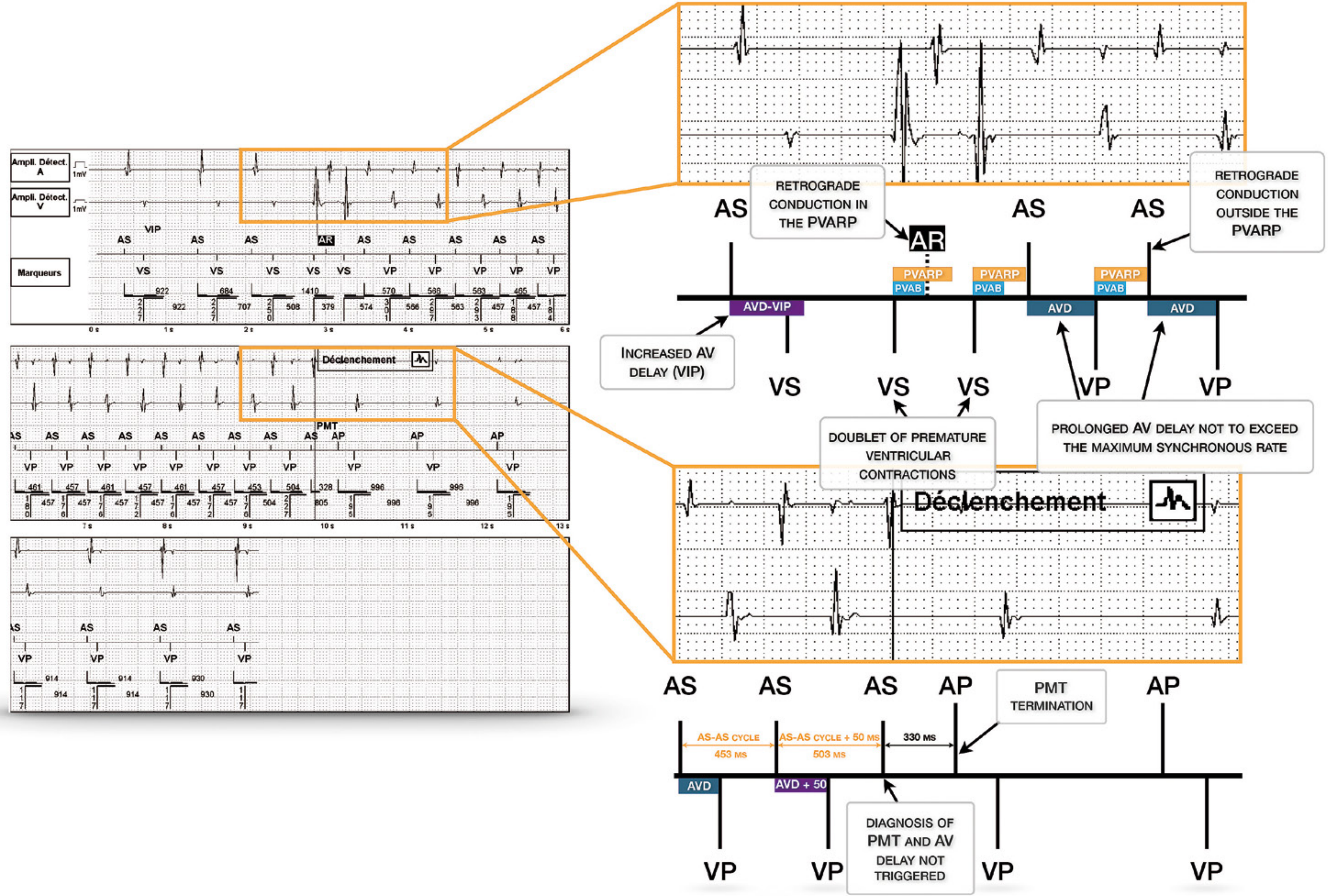
4) the device confirms the relationship between ventricular pacing and atrial sensing (ventricular pacing leading to retrograde atrial conduction), by modifying the AV delay by 50 ms on the ninth cycle (prolonging or shortening of the AV delay); if the next VP-AS interval (tenth cycle) is unchanged from the previous VP-AS interval, the device confirms the diagnosis of PMT; indeed the latter reflects the fact that activation of the atrium is dependent on ventricular pacing; if the VP-AS interval is modified (more than 16 ms difference), the diagnosis of PMT is reversed, no termination attempt is made and the search for PMT resumes only after 256 cycles so as not to multiply the interventions due to an episode of sinus tachycardia; it should be noted that on older platforms, the device did not compare the duration of the VP-AS interval of the tenth cycle with that of the ninth cycle but with an average of the VP-AS intervals of the first 8 cycles;

5) if the VP-AS interval is not impacted by the change in AV delay, the device concludes to PMT, atrial activity does not trigger an AV delay, ventricular pacing is inhibited, and atrial pacing is delivered 330 ms after this AS cycle with resumption of normal atrioventricular synchrony; this atrial pulse is inhibited if an atrial activity (AS) is sensed during a sensing period of 210 ms after the absolute atrial refractory period;

The various programmable parameters are therefore:

PMT Response: Off/Passive/Atrial Pace

PMT Detection Rate: 90, ..., 130, ..., 180 beats/minute


Ampl. Détect. A
Ampl. Détect. V
Marqueurs
Déclenchement
PMT
AS
AR
RETROGRADE CONDUCTION IN THE PVARP
RETROGRADE CONDUCTION OUTSIDE THE PVARP
PVARP
PVAB
AVD-VIP
AVD
INCREASED AV DELAY (VIP)
VS
VP
DOUBLET OF PREMATURE VENTRICULAR CONTRACTIONS
PROLONGED AV DELAY NOT TO EXCEED THE MAXIMUM SYNCHRONOUS RATE
AP
PMT TERMINATION
AS-AS CYCLE 453 MS
AS-AS CYCLE + 50 MS 503 MS
330 MS
AVD + 50
DIAGNOSIS OF PMT AND AV DELAY NOT TRIGGERED

Patient

Same patient as in the previous tracing; other episode diagnosed as PMT and recorded in the device memory.

Quiz

Which answer(s) is(are) true regarding this tracing?

A. this is most likely a VT episode

B. this is most likely a PMT

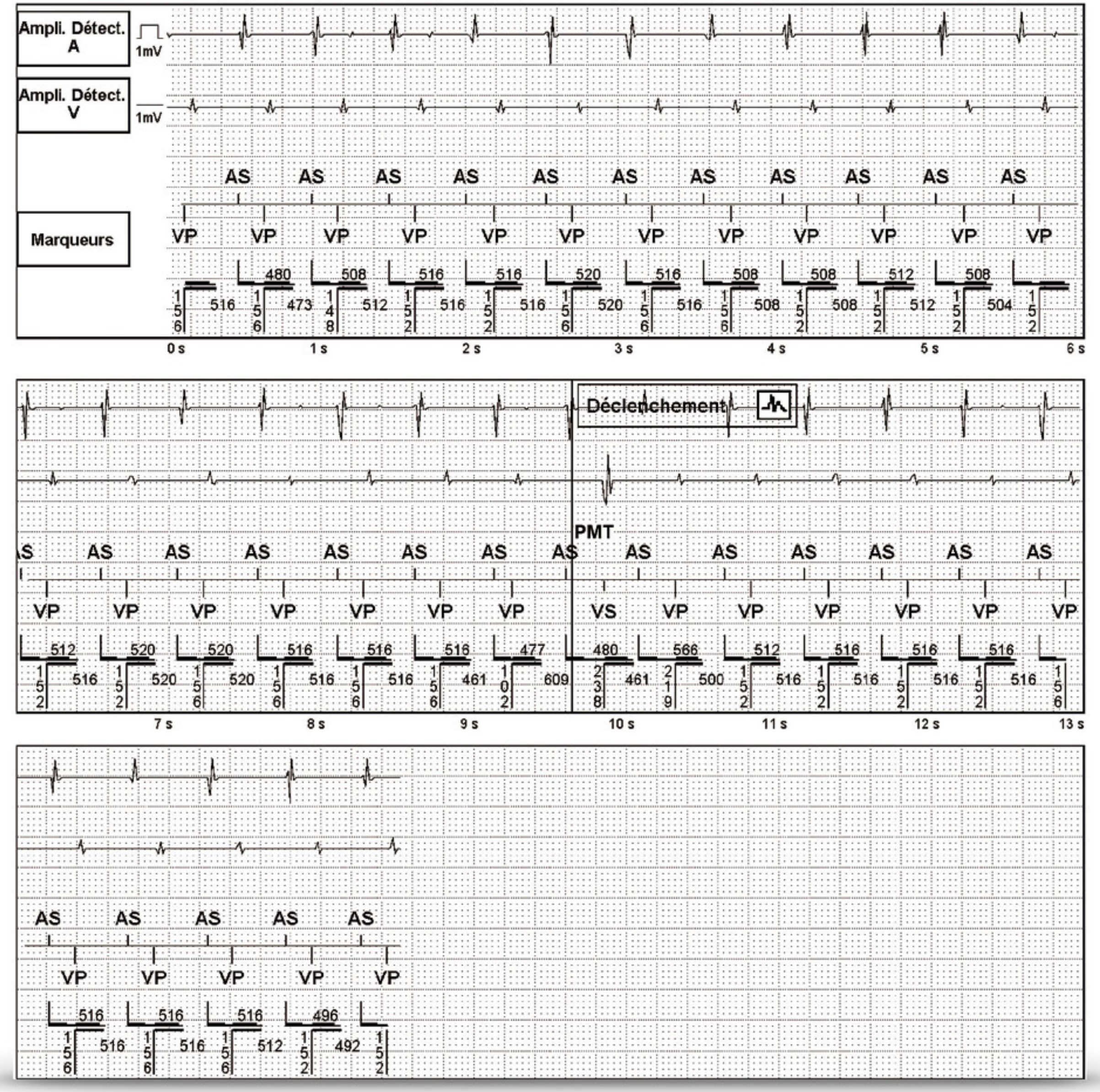
C. this is most likely a sinus tachycardia episode

D. this is most likely an AF episode

E. this is most likely a 2:1 flutter episode

ANSWER(S)

Refractory periods



AS Atrial sensing
VS Ventricular sensing
VP Ventricular pacing

Tracing 30: sinus tachycardia and false diagnosis of pacemaker-mediated tachycardia

SUMMARY

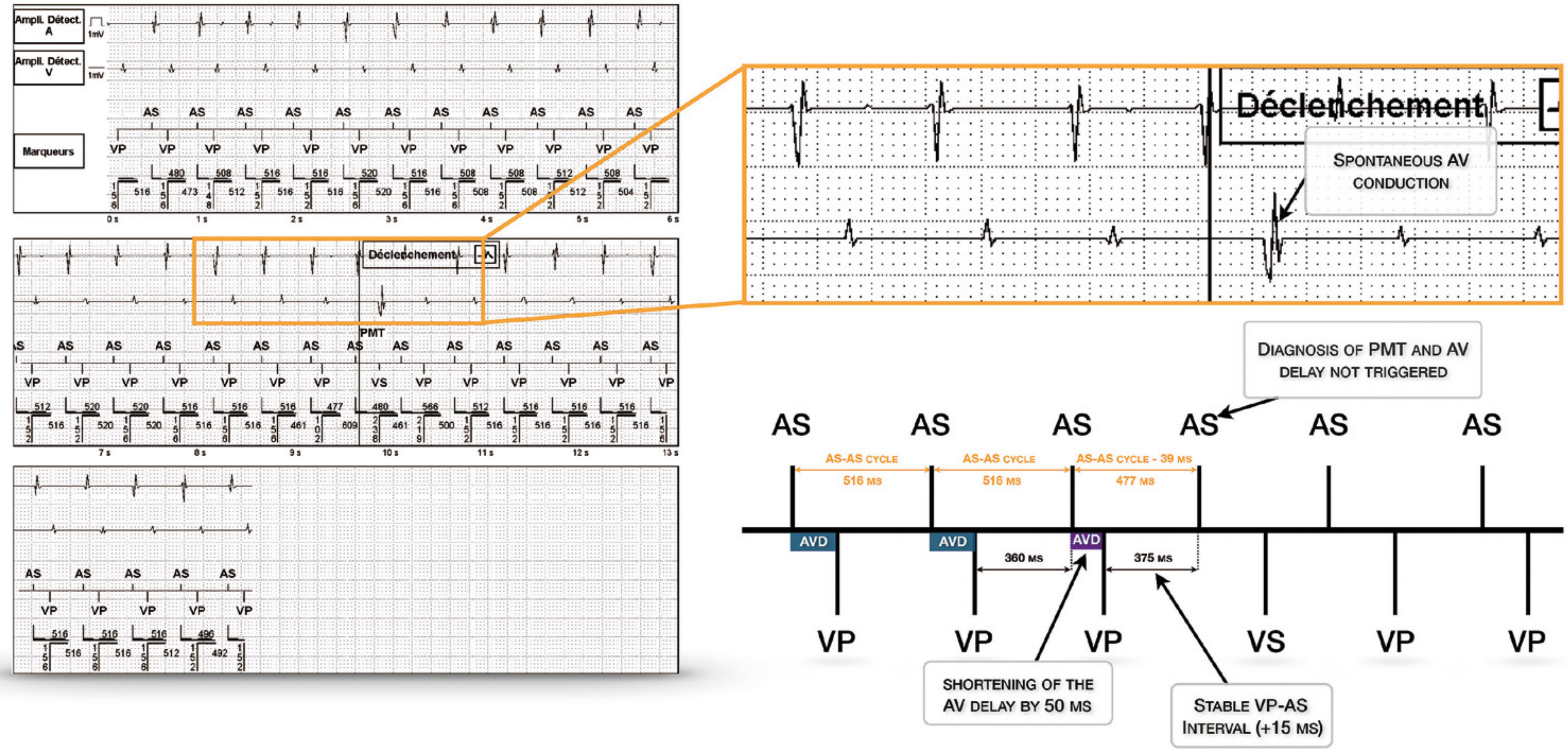
TRACING

At the beginning of tracing, AS-VP cycles with varying AS-AS and VP-AS intervals of more than 40 ms between cycles (480 to 520 ms); stabilization of these intervals in a second phase; suspicion of PMT (atrial rate above the PMT rate limit and stable VP-AS intervals); shortening of the AV delay for one cycle (from 150 to 100 ms); on the next cycle, shortening of the VP-AS interval highly suggestive of a PMT; the ensuing atrial activity does not trigger an AV delay; intrinsic atrioventricular conduction highly suggestive of sinus tachycardia; this VS cycle inhibits atrial pacing; on the ensuing cycle, the AS-AS cycle remains relatively short which demonstrates the presence of a sinus tachycardia wrongly diagnosed as PMT by the device.

COMMENTS

The PMT diagnosis and termination algorithm varies according to the different manufacturers, but is based on the multi-cycle repetition of atrial sensing and ventricular pacing displaying a high rate and a fixed VP-AS coupling. The PMT detection algorithm requires 8 (Abbott™ pacemakers, Biotronik™, Livanova™ and Medtronic™) or 16 (Boston Scientific™) consecutive VP-AS cycles. The detection algorithm requires that the PMT be at the maximum monitoring rate (Boston Scientific™ pacemakers), that the rate be greater than 100 bpm (Biotronik™ pacemakers) or that the intervals are less than 470 ms (Livanova™ pacemakers). This parameter is programmable on Abbott™ pacemakers. A stability criterion for VP-AS intervals is included in the Abbott™, Biotronik™, Boston Scientific™ and Livanova™ pacemaker algorithm. The algorithm includes a confirmation phase with AV delay modification for Abbott™, Biotronik™, Livanova™ pacemakers and the latest Medtronic™ pacemaker models. This confirmation phase changes the AV delay to effectively differentiate sinus tachycardia and PMT as explained on the previous tracing. A few isolated cases of misclassification during an episode of sinus tachycardia have been described. The occurrence of a premature atrial contraction following a shortening of the AV delay may skew the diagnosis giving the impression that the change in AV delay has had an impact on the ensuing VP-AS delay (prematurity of the atrial extrasystole). In this example, the pacemaker shortens the AV delay for one cycle upon suspicion of a PMT. The following VP-AS interval is obviously shorter than the previous interval (+16 ms) leading to the diagnosis of PMT. This shortening is not related to the change in AV delay but to a variation of the AS-AS intervals found at the beginning of the tracing. The ensuing AS-AS cycle remains at a value close to 480 ms, which is highly suggestive of sinus tachycardia, just as the fact that the AS cycle, which did not trigger an AV delay, is followed by an intrinsic QRS complex (VS). Throughout the tracing, we can observe variations in AS-AS cycle interval most likely of respiratory origin.

The PMT diagnosis and termination algorithm includes a confirmation phase allowing the differential diagnosis between PMT and sinus tachycardia and thereby avoiding untimely interventions due to sinus tachycardia. In rare cases (premature atrial contraction, respiratory variability of atrial sensing), the algorithm may be misled resulting in an atrial activity not followed by ventricular pacing.


Ampli. Détect. A
Ampli. Détect. V
Marqueurs
Déclenchement
PMT
SPONTANEOUS AV CONDUCTION
DIAGNOSIS OF PMT AND AV DELAY NOT TRIGGERED
AS-AS CYCLE 516 MS
AS-AS CYCLE 516 MS
AS-AS CYCLE - 39 MS 477 MS
AVD
360 MS
375 MS
AS AS AS AS AS AS
VP VP VP VS VP VP
SHORTENING OF THE AV DELAY BY 50 MS
STABLE VP-AS INTERVAL (+15 MS)

Patient

71-year-old man, implanted with an Assurity™ + DR dual-chamber pacemaker for paroxysmal syncopal complete atrioventricular block; during the interrogation, highlighting of an AT/AF episode stored in the device memory.

Quiz

Which answer(s) is(are) true regarding this tracing?

A. this is an atrial tachycardia episode

B. this is a PMT

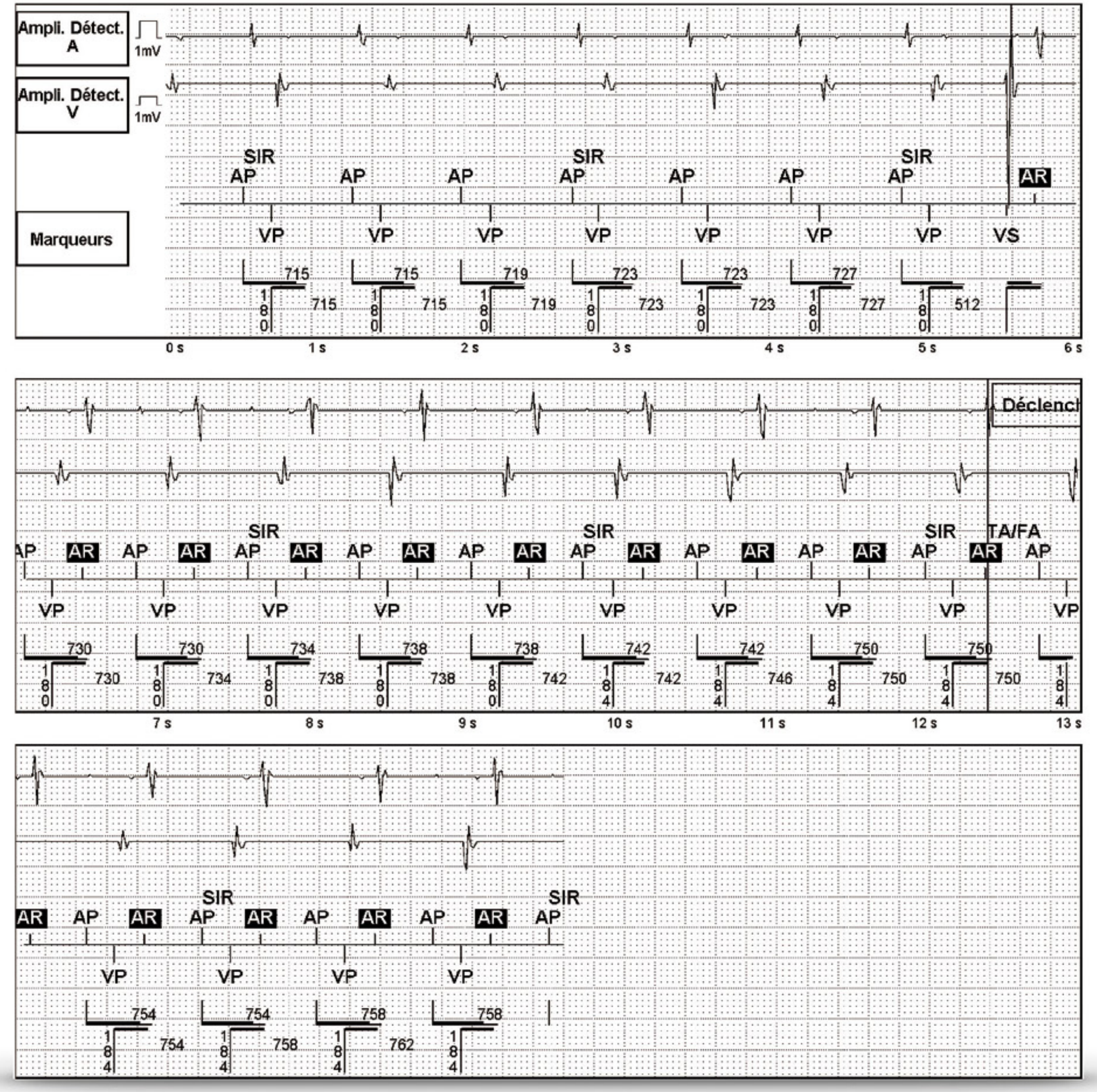
C. there is an increase in atrial threshold

D. in the second portion of the tracing, atrial activation is retrograde (AR)

E. in the second portion of the tracing, atrial pacing is ineffective since occurring in the atrial refractory period

ANSWER(S)

Refractory periods



AR Atrial sensing in PVARP
AP Atrial pacing
VP Ventricular pacing

Tracing 31: repetitive nonreentrant ventriculoatrial synchrony

SUMMARY

TRACING

The tracing begins with AP-VP cycles with effective atrial and ventricular pacing at the sensor rate (SIR, rate modulation); a premature ventricular contraction is followed by retrograde conduction and sensing of atrial activity in the PVARP (AR); the following atrial pacing is ineffective since occurring in the refractory period following the preceding atrial depolarization; the cycle is repeated with retrograde conduction in PVARP and ineffective atrial pacing favoring retrograde conduction; the filtered atrial rate is calculated based on the intrinsic (AR or AS) but also paced (AP) cycles, which explains the recording of an episode diagnosed as AT/AF.

COMMENTS

This tracing illustrates a particular and often underdiagnosed form of repetitive loss of atrial capture. Sensing of retrograde conduction occurs in the PVARP (functional undersensing) and is responsible for inefficient atrial pacing (loss of functional capture) since delivered in the physiological refractory period. This patient presented a normal atrial pacing threshold (<1V for 0.5 ms) with a suitable programming margin (2.5 Volts for 0.5 ms). A repetitive nonreentrant ventriculoatrial synchrony begins when a premature ventricular contraction is followed by a retrograde atrial conduction that falls within the PVARP. The ensuing atrial pacing is ineffective since falling within the physiological atrial refractory period (loss of functional capture). At the end of the AV delay, ventricular pacing is delivered and is followed by retrograde conduction triggering repetitive retrograde atrial conduction, inefficient atrial pacing and ventricular pacing cycles. This is not a reentry (unlike a PMT), since retrograde atrial activity does not trigger ventricular pacing.

This type of repetitive sequences is preferentially diagnosed on the Abbott™ pacemakers by the peculiarity of their fallback algorithm function (the only one to integrate the AP cycles in the computation of the filtered atrial rate) which leads to the recording of an AT/AF episode. This type of problem is therefore underdiagnosed by other manufacturers although likely not less frequent.

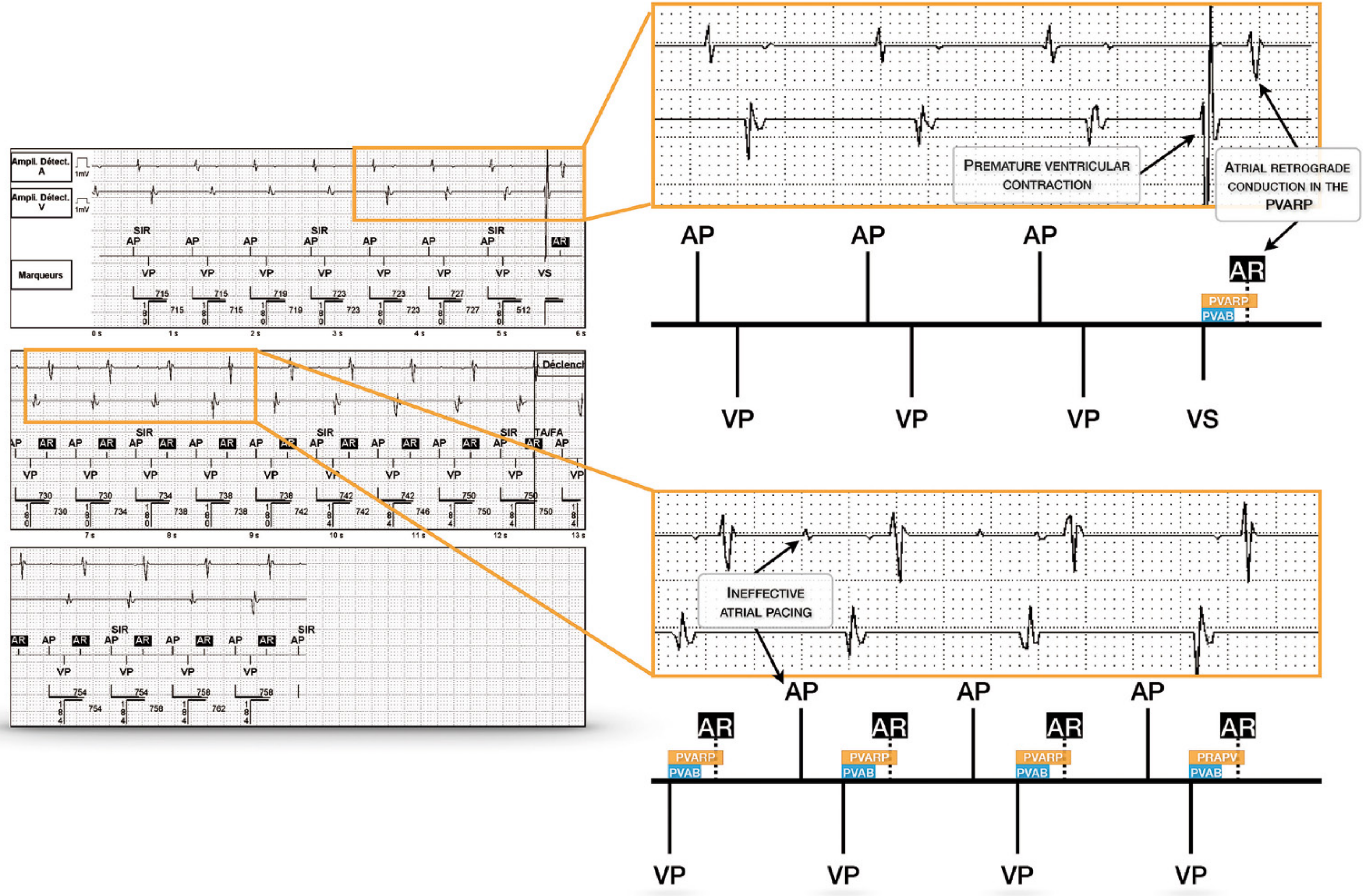
For this type of repetitive sequences to begin, 2 elements must be available: 1) a dual- or triple-chamber pacemaker programmed in DDD, DDDR, DDI or DDIR mode but not for the VDD mode since atrial pacing is required (difference with a PMT which is not possible with a DDI mode but possible with a VDD mode); 2) the presence of retrograde conduction.

Certain programming elements can also favor its occurrence: 1) high pacing rate (more common when the rate response or an atrial overdrive algorithm is programmed), the AR-AP interval being reduced (greater probability of atrial pacing being ineffective); 2) programming a long AV delay (favors retrograde conduction); 3) programming of a prolonged PVARP.

This type of repetitive sequence can induce a pacemaker syndrome, unnecessarily increase the percentage of ventricular pacing, is a cause of false diagnosis of atrial arrhythmia and can be arrhythmogenic (possible induction of a true AF episode).

To avoid this type of problem, different programming options can be considered: 1) lowering the minimum rate if the latter is high; 2) deprogramming rate response modulation if not absolutely essential; indeed, atrial pacing occurs much earlier relative to retrograde activation if rate modulation is programmed which increases the risk of loss of functional capture; 3) decreasing the value of the AV delay; 4) shortening the PVARP.

This type of repetitive sequence is often underdiagnosed and can lead to the occurrence of pacemaker syndrome. Abbott™ pacemakers are the only pacemakers that allow their recording in the form of false AT/AF episodes in the device memory.


Ampli. Détect. A
Ampli. Détect. V
Marqueurs
Déclench
SIR
TA/FA
Premature ventricular contraction
Atrial retrograde conduction in the PVARP
Ineffective atrial pacing
AP
VP
VS
AR
PVARP
PVAB
PRAPV

CHAPTER 5

Management of arrhythmias and oversensing

Patient

64-year-old man, implanted with an Assurity™ + DR dual-chamber pacemaker for complete atrioventricular block; during the interrogation, highlighting of an AMS episode stored in the device memory.

Quiz

Which answer(s) is(are) true regarding the automatic mode switching algorithm?

A. AMS occurs when the filtered atrial rate interval (FARI) < the atrial tachycardia detection interval

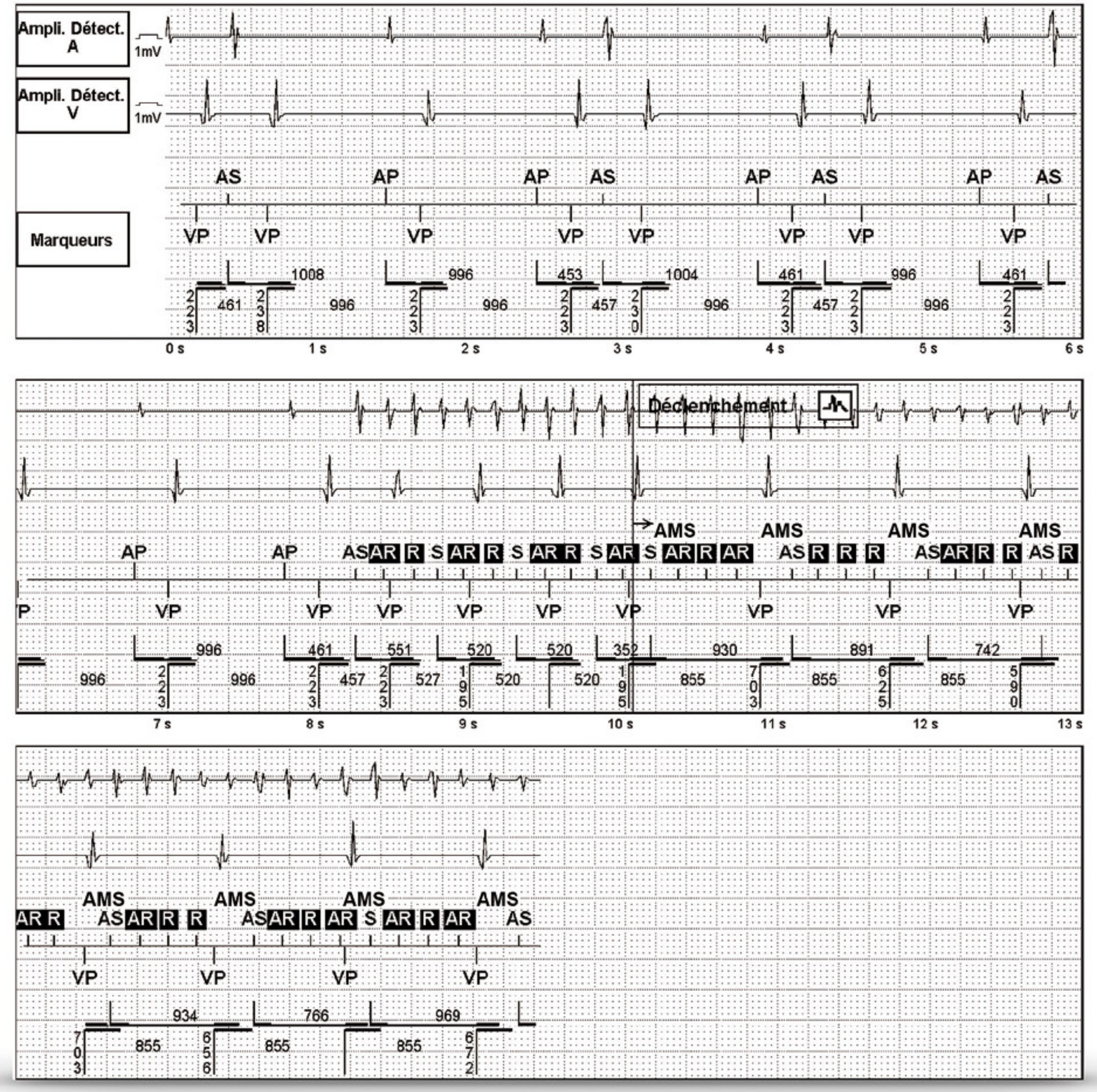
B. if actual PP ≤ FARI: FARI decremented by 39 ms

C. if actual PP> FARI: FARI incremented by 23 ms

D. return to synchronous mode when FARI > the maximum synchronous rate interval

E. return to synchronous mode when FARI > the atrial tachycardia detection interval

ANSWER(S)



AS Atrial sensing
AR Atrial sensing PVARP
AP Atrial pacing
VP Ventricular pacing

Tracing 32: automatic mode switching

SUMMARY

TRACING

Atrial pacing and ventricular pacing; classified (AS) premature atrial contraction followed by an extended AV delay so as not to exceed the maximum synchronous rate (130 beats/minute); onset of an atrial arrhythmia; each short atrial cycle decrements the filtered atrial rate by 39 ms; before mode switching, acceleration of the ventricular pacing rate; AMS when the filtered atrial rate interval (FARI) falls below the atrial tachycardia detection interval; slowing of the ventricular pacing rate.

COMMENTS

The management of pacemaker patients with atrial arrhythmia episodes is complex given the different types of mechanisms known to trigger atrial arrhythmias and the risk of runaway ventricular pacing due to sensing of a rapid atrial rhythm. The device can be programmed to respond to atrial arrhythmia by switching to an asynchronous mode in order to avoid high-rate ventricular pacing which can compromise hemodynamic stability. Mode switching is the ability of the pacemaker to automatically switch from an atrial tracking mode (DDD or VDD) to a non-atrial tracking mode (DDI or VDI). The ventricular pacing rate gradually progresses from the maximum synchronous rate to the response rate or the minimum rate. This avoids a sudden drop in the ventricular rate. Upon termination of the atrial tachyarrhythmia, mode switching reverts to the programmed synchronous pacing mode.

The ideal mode switching algorithm has the following characteristics: fast triggering to avoid prolonged rapid ventricular pacing during the initial detection phase of the arrhythmia; ability to quickly revert to a synchronous mode at the end of the arrhythmia episode; good atrial arrhythmia diagnostic capabilities even in the presence of atrial signals of varying amplitude and rate; ability to avoid mode switching in response to crosstalk, noise or sinus tachycardia.

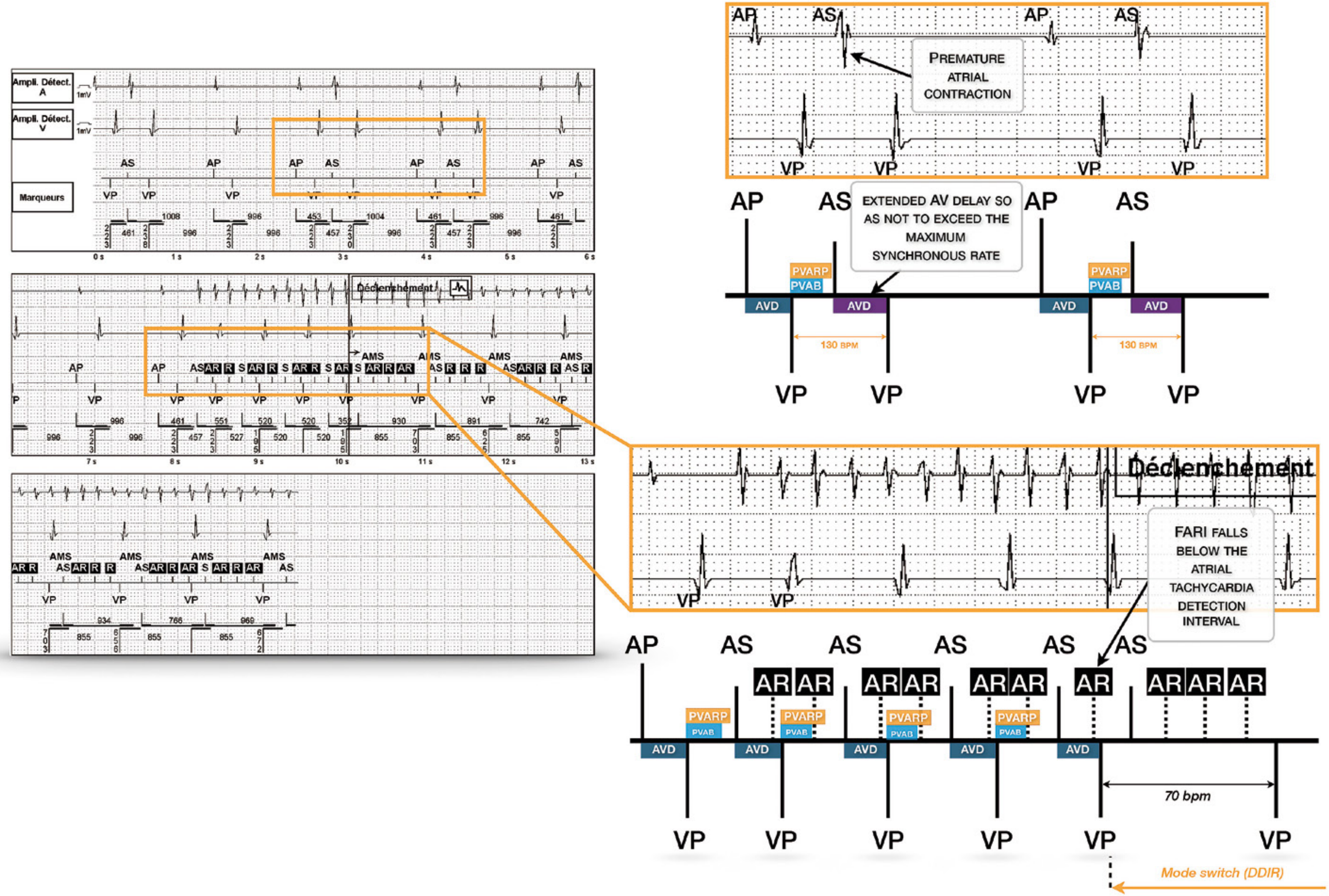
The fallback algorithm used by Abbott™ pacemakers features certain specificities that are important to know. Automatic mode switching (AMS) uses a filtered, not actual, atrial rate based on a comparison of the current atrial rate with a continually updated average rate. Automatic mode switching (AMS) to DDI(R) or VVI(R) mode occurs when the filtered atrial rate surpasses the atrial tachycardia detection rate (ATDR). The pacemaker measures the actual PP interval at each cycle and calculates a filtered atrial rate interval (FARI) according to the following rule: if the actual PP interval is ≤ FARI, the FARI is decremented by 39 ms; if the actual PP interval is > FARI: the FAI is incremented by 23 ms. The atrial activities sensed in the PVARP, contrary to signals in the blanking period, are taken into account in the calculation of the FARI. Mode switching occurs as soon as the filtered atrial interval falls below the atrial tachycardia detection interval.

During mode switching, the pacing rate corresponds to the AMS base rate (programmable independently of the base rate) or the rate indicated by the sensor (rate response). The return to synchronous mode is only possible if the atrial rate falls below the maximum synchronous rate (FARI > the maximum synchronous rate interval) and not below the atrial tachycardia detection rate.

The criterion for recording AT/AF episodes is slightly different from that of AMS. The calculation method for the filtered atrial interval (FARI) is identical. To record an episode, 5 non consecutive cycles with a PP interval and a FARI that are below the atrial tachycardia detection rate are needed. These consecutive cycles allow avoiding the recording of AMS episodes due to crosstalk (alternating short cycles-long cycles which can cause AMS but not the recording of the episode due to absence of consecutive short cycles). The AMS criterion is more sensitive than the recording criterion which is conversely more specific. Nine consecutive with a PP interval and an FARI greater than the atrial tachycardia detection rate are thus needed for the episode to be terminated (2 episodes less than 20 seconds apart are considered as a single AT/AF episode).

The AT/AF burden is the percentage of time spent in AT/AF over a 52-week period. Each data point on the graph corresponds to the percentage of time the patient was in AT/AF over a seven-day period.

The functioning of the fallback algorithm is very specific and based on the analysis of the filtered atrial rate based on a comparison of the current atrial rate with a continuously updated filtered rate. The goal is to fall back only on a sustained tachycardia and not on a few intermittent fast cycles.



Ampli. Détect. A
Ampli. Détect. V
Marqueurs
Déclenchement
PREMATURE ATRIAL CONTRACTION
EXTENDED AV DELAY SO AS NOT TO EXCEED THE MAXIMUM SYNCHRONOUS RATE
AP
AS
VP
PVARP
PVAB
AVD
130 BPM
FARI FALLS BELOW THE ATRIAL TACHYCARDIA DETECTION INTERVAL
AR
70 bpm
Mode switch (DDIR)

Patient

59-year-old man with obstructive hypertrophic cardiomyopathy implanted with an Accent™ DR pacemaker aimed at reducing the left intraventricular gradient; episode of sudden syncope; highlighting of a high ventricular rate episode at the time of the syncope.

Quiz

Which answer(s) is(are) true regarding this tracing?

A. this is an atrial tachycardia episode

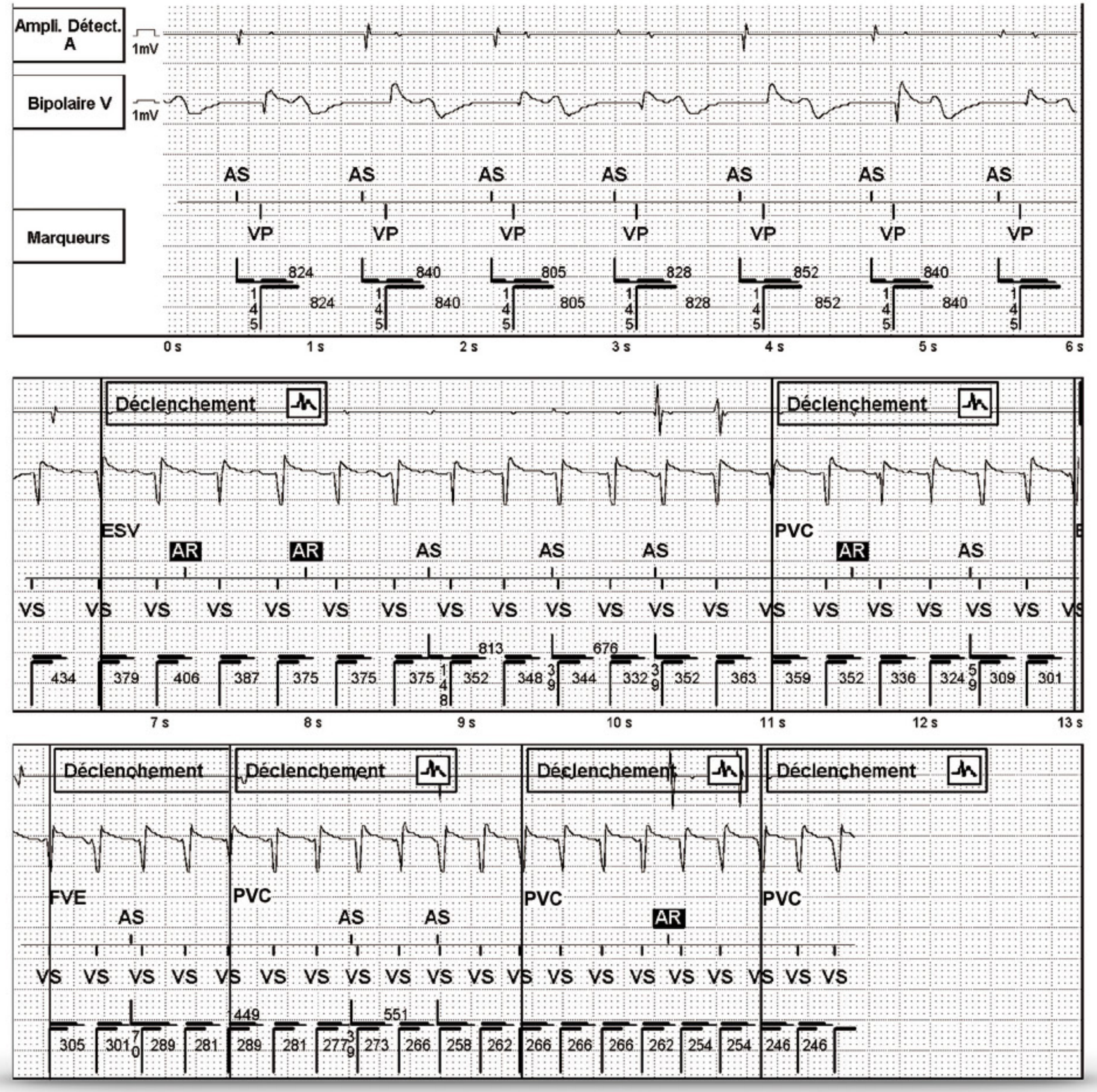
B. this is a VT episode

C. this is a junctional tachycardia episode

D. this is a PMT episode

E. this is a fallback failure due to atrial arrhythmia

ANSWER(S)



AS Atrial sensing
AR Atrial sensing in PVARP
AP Atrial pacing
VS Ventricular sensing
VP Ventricular pacing

Tracing 33: high ventricular rate

SUMMARY

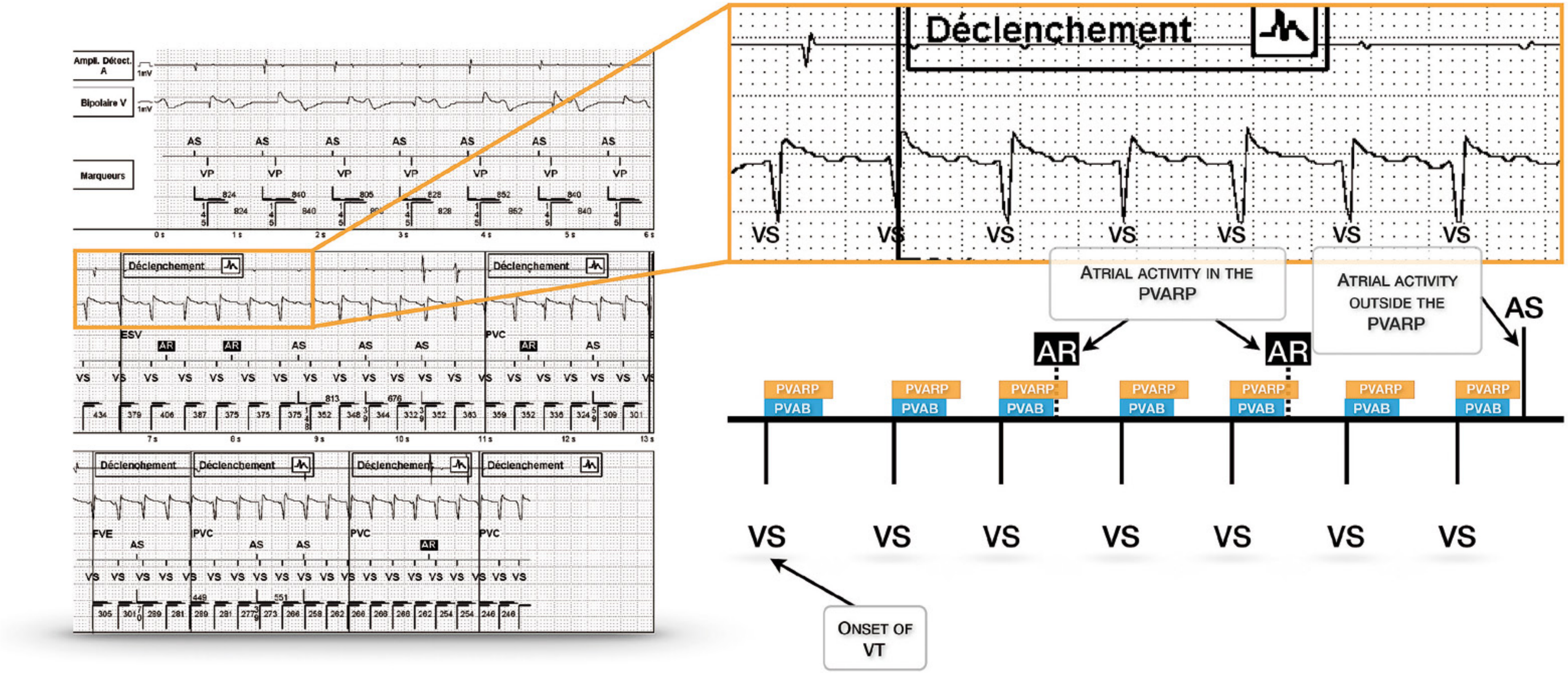
TRACING

At the beginning of the tracing, atrial sensing and ventricular pacing; VT episode with atrioventricular dissociation; acceleration of the VT rate which becomes very rapid (240 bpm) thus explaining the syncope.

COMMENTS

This tracing poses the difficult question of recording bursts of non-supported ventricular tachycardia in pacemaker patients. For this patient, it would appear legitimate to discuss upgrading to an implantable ICD. The indication is furthermore warranted in this patient with hypertrophic cardiomyopathy and syncopal VT episode.

Recording episodes of non-supported ventricular tachycardia in pacemaker-implanted patients is relatively common. Management varies depending on the presence of symptoms and the presence of heart disease which may justify the decision to upgrade to an implantable ICD.


Ampli. Détect. A
Bipolaire V
Marqueurs
AS
VP
ESV
PVC
FVE
Déclenchement
VS
Atrial activity in the PVARP
Atrial activity outside the PVARP
AS
AR
PVARP
PVAB
Onset of VT

Patient

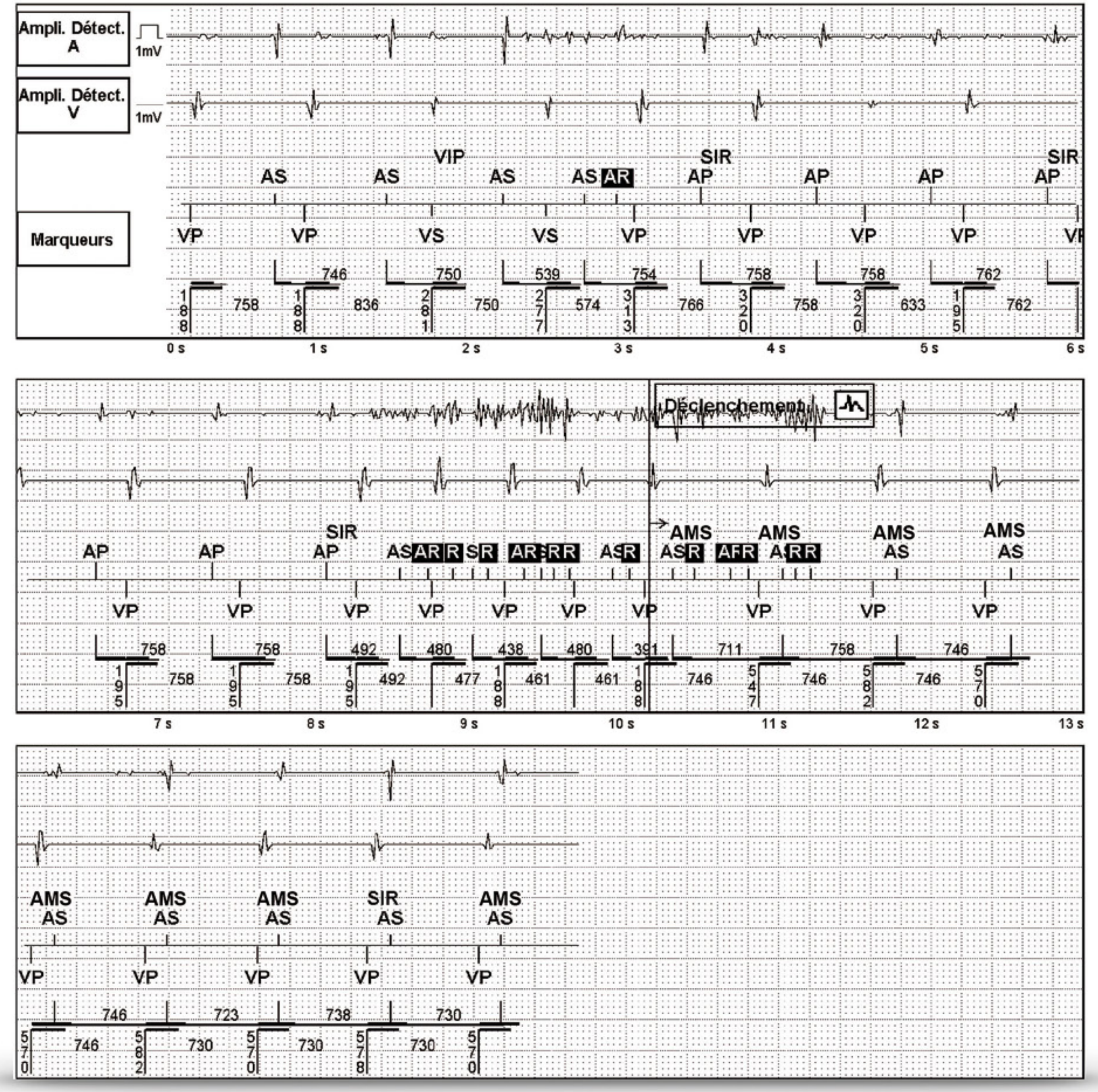
69-year-old man implanted with an Assurity MRI™ pacemaker for paroxysmal atrioventricular block; recording of multiple AMS episodes in the device memory.

Quiz

Which answer(s) is(are) true regarding this tracing?

A. the AMS occurs in the setting of atrial arrhythmia
B. the AMS occurs in the setting of crosstalk
C. the AMS occurs in the setting of the oversensing of a 50 Hz signal
D. the AMS occurs in the setting of the oversensing of noise on the atrial lead
E. the AMS occurs in the setting of sinus tachycardia

ANSWER(S)



AS Atrial sensing
AR Atrial sensing in the PVARP
AP Atrial pacing
VS Ventricular sensing
VP Ventricular pacing

Tracing 34: atrial and ventricular oversensing

SUMMARY

TRACING

Oversensing of a very fast, disorganized, non-physiological signal at the level of the atrial lead; accelerated ventricular pacing before the occurrence of fallback; fallback to DDIR mode (AMS) with loss of atrioventricular synchrony (not followed by intrinsic atrial activities).

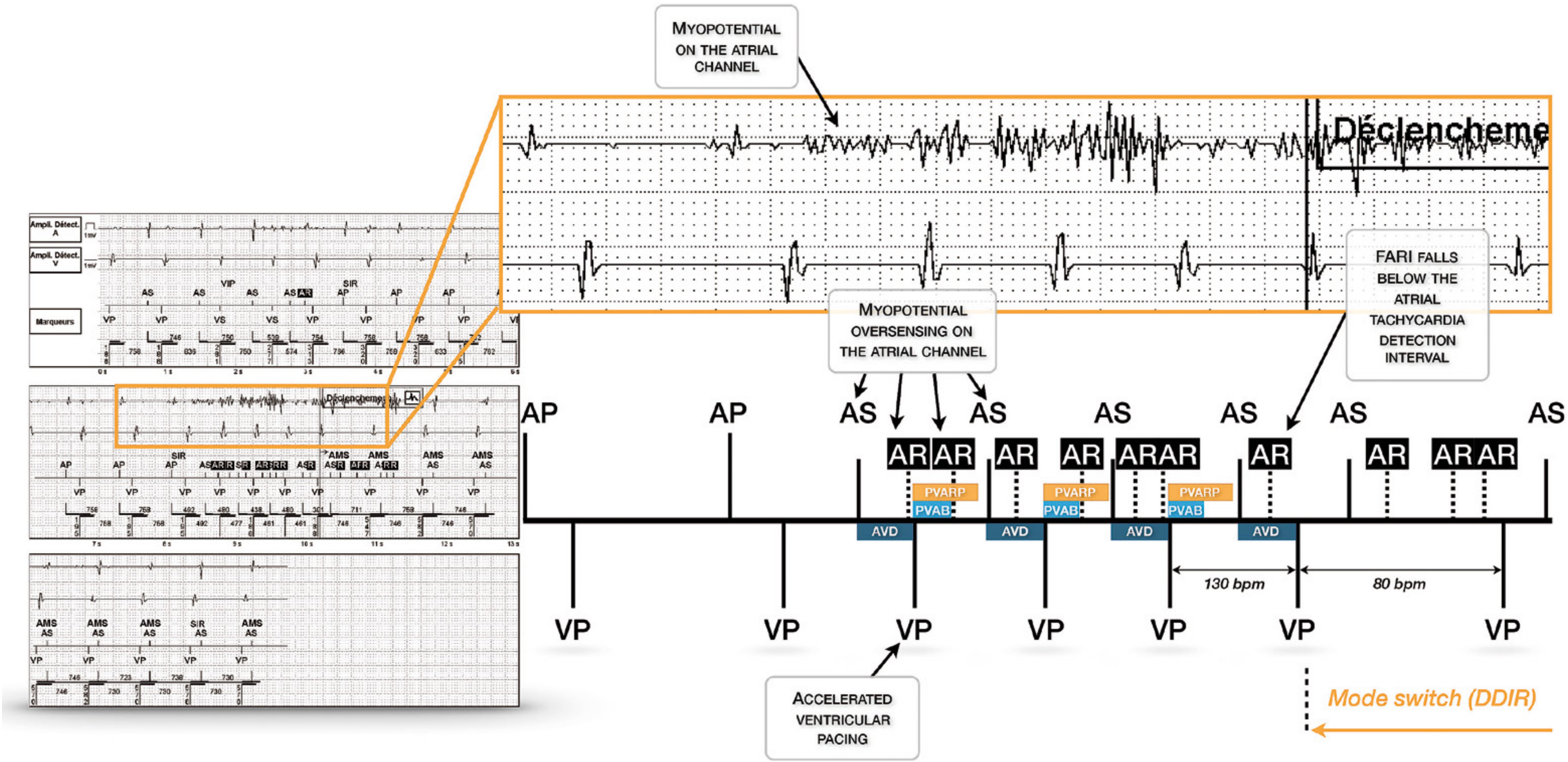
COMMENTS

Both of these patients presented an oversensing of myopotentials at the level of the atrial lead (first patient) or ventricular lead (second patient) responsible for multiple episodes of AMS or HVR. The oversensing was reproducible through counter maneuvers.

Oversensing of pectoral myopotentials was relatively common in patients implanted with a pacemaker operating in unipolar mode and could result in inhibition of pacing and syncope in pacemaker-dependent patients. The programming of triggered modes (AAT, VVT, DDT) could be proposed in this setting in order to avoid the occurrence of significant pauses. When sensing is programmed in bipolar mode, given that the can is positioned in the pocket near the pectoral muscles and thus not part of the sensing circuit, the pectoral myopotentials should not therefore induce any oversensing. On the other hand, in the presence of an insulation break (typically an erosion leading to current leakage) at the pocket portion of the lead (friction between the pulse generator and the lead), the sensing channel can then oversense the pectoral myopotentials which can cause inhibition of pacing and lead to false diagnoses of VT (HVR) or AF (AMS) depending on the lead. Analysis of the EGMs reveal, in this setting, the presence of very fast (high frequency), non-physiological signals. The oversensing can be replicated by isometric movements of the arm ipsilateral to the can or by manipulation of the lead in the pocket.

Upon suspicion of pectoral myopotential oversensing, a chest x-ray must be performed along with a complete control verification of the device (impedance values, pacing and sensing thresholds). The presence of an abnormally low pacing impedance value or a sharp decrease in this value is suggestive of an insulation break. If the episodes multiply

Myopotential oversensing is evoked when there is evidence of high frequency, disorganized, low-amplitude signals. Diaphragmatic myopotentials can be replicated by specific maneuvers (deep inspiration, Vasalva, forced cough) while their amplitude varies with the respiratory cycle. The oversensing of pectoral myopotentials can be replicated by isometric movements of the arm ipsilateral to the can or by manipulation of the lead in the pocket.

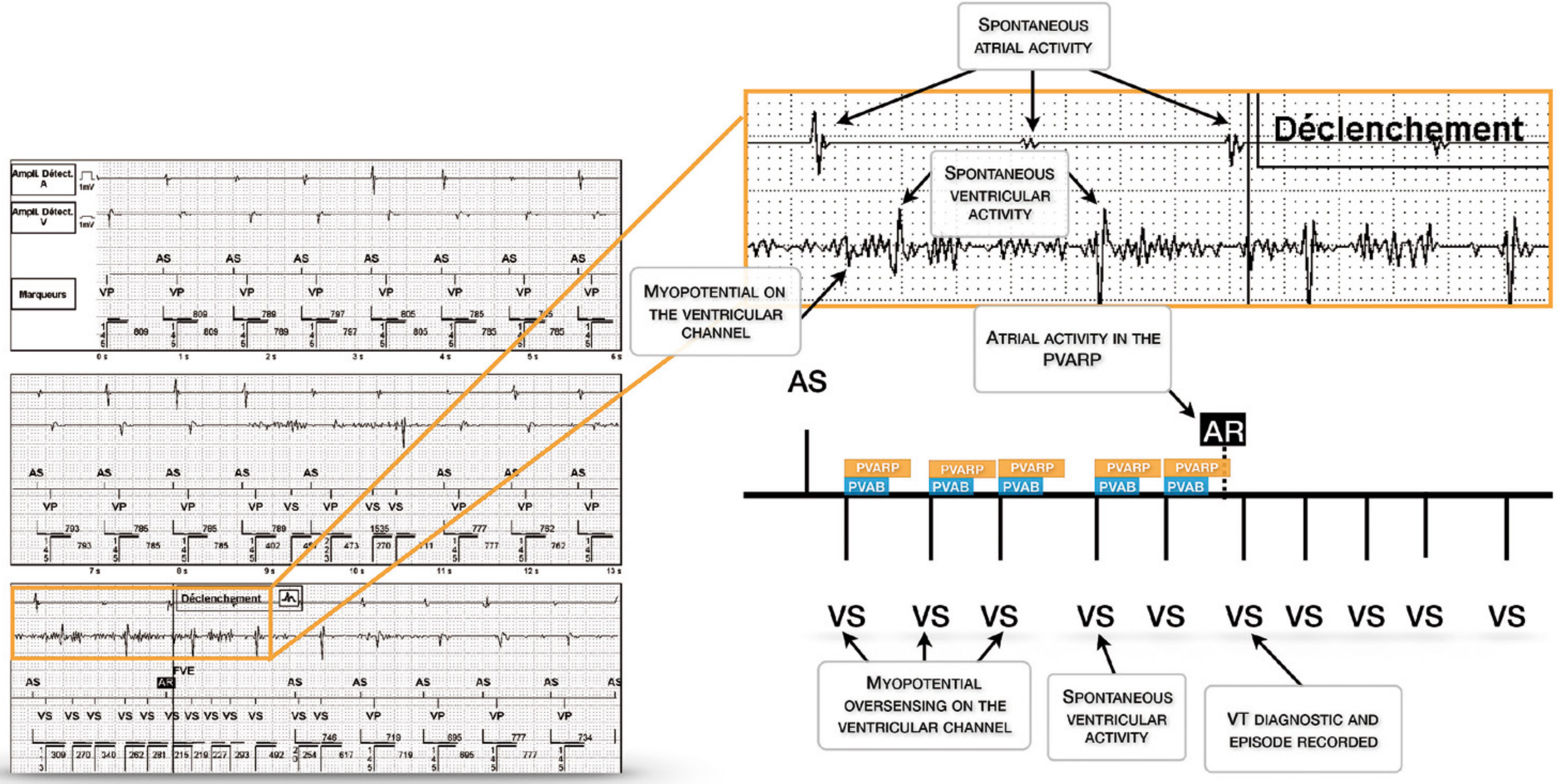

Myopotential on the atrial channel
Déclencheme
Myopotential oversensing on the atrial channel
FARI falls below the atrial tachycardia detection interval
AP
AP
AS
AS
AS
AS
AS
AS
AR
AR
AR
AR
AR
AR
AR
AR
AR
AR
PVARP
PVAB
PVARP
PVAB
PVARP
PVAB
AVD
AVD
AVD
AVD
130 bpm
80 bpm
VP
VP
VP
VP
VP
VP
VP
Accelerated ventricular pacing
Mode switch (DDIR)

Patient

61-year-old man implanted with an Assurity MRI™ pacemaker for paroxysmal atrioventricular block; recording of several episodes of HVR in the device memory.

TRACING

Atrial sensing and ventricular pacing; oversensing of a very fast, disorganized, non-physiological signal at the level of the ventricular lead inhibiting ventricular pacing; absence of ventricular pause since the patient is not pacemaker-dependent (intrinsic QRS complexes remain viewable).


Spontaneous atrial activity
Déclenchement
Spontaneous ventricular activity
Myopotential on the ventricular channel
Atrial activity in the PVARP
AS
AR
PVARP
PVAB
VS VS VS VS VS VS VS VS VS VS
Myopotential oversensing on the ventricular channel
Spontaneous ventricular activity
VT diagnostic and episode recorded
Ampli. Détect. A
Ampli. Détect. V
Marqueurs
FVE

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