Tech Corner

Anti-PMT (Pacemaker Mediated Tachycardia) algorithm

NOTE: PLEASE NOTE THAT THE FOLLOWING INFORMATION IS A GENERAL DESCRIPTION OF THE FUNCTION. DETAILS AND PARTICULAR CASES ARE NOT DESCRIBED IN THE ARTICLE. FOR ADDITIONAL EXPLANATION PLEASE CONTACT YOUR SALES REPRESENTATIVE.

MicroPort™ CRM

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AVAILABILITY

This Anti-PMT algorithm is available on all Microport CRM dual-chamber and triple-chamber devices.

Pacing modes	**Pacemakers/CRT-P**	**ICDs/CRT-D**
DDD	Yes	Yes
SafeR	Yes	Yes
VDD	Yes	Not Applicable
DDT	Yes	Not Applicable

SYNONYM

ELT = Endless Loop Tachycardia

OBJECTIVE

The Anti-PMT algorithm is intended to protect the patient from Pacemaker-Mediated Tachycardia (PMT) without reducing the atrial sensing capability of the device.

DEFINITION

A pacemaker mediated tachycardia (PMT) describes a repetitive sequence of sensed retrograde atrial events (P') followed by ventricular pacing. This phenomenon has been observed and understood early after the introduction of dual-chamber pacing in patients presenting with retrograde conduction (*i.e.* intrinsic ventriculo-atrial conduction).

A Pacemaker Mediated Tachycardia is initiated when the ventricular activity is conducted in a retrograde way to the atria, resulting in a premature atrial depolarization, *i.e* an hemodynamic AV dissociation. The pacemaker senses the retrograde P wave (P') outside the refractory periods, which triggers the AV delay and ventricular pacing. If the ventricular event is again retrogradely conducted to the atrium, the cycle may develop into what is known as a Pacemaker-Mediated Tachycardia (PMT), which often drives the ventricular rate to the Maximum Tracking Rate.

The PMT will continue until there is a retrograde block (VA block) or the intervention of the Anti-PMT algorithm.

Anterograde conduction: Transmission of a cardiac impulse in the normal direction, from the sinus node to the ventricles: forward conduction through the AV node.

Retrograde conduction: Transmission of a cardiac impulse backward from the ventricles or AV node to the atria. The retrograde conduction can take place through the AV node, the myocardial tissues or other circuits (called accessory circuits or pathways).

CLINICAL BACKGROUND: ORIGIN OF A PMT

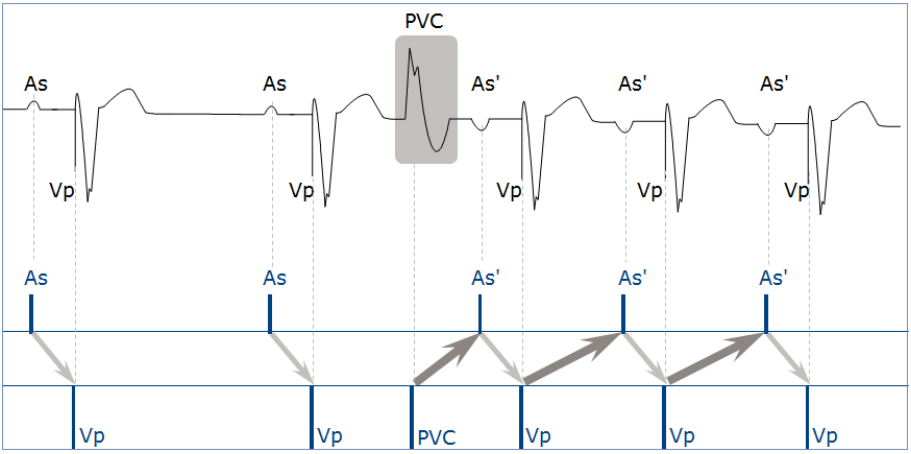
The onset of a PMT implies:

- the programming of an atrial-tracking pacing mode (DDD or VDD)
- the temporary or permanent loss of the AV synchrony (if the ventricular activity is correctly synchronized with the atrial activity, the retrograde conduction is blocked).

There are various phenomena that may induce AV dissociation, and if retrograde conduction is present, it can potentially trigger a PMT:

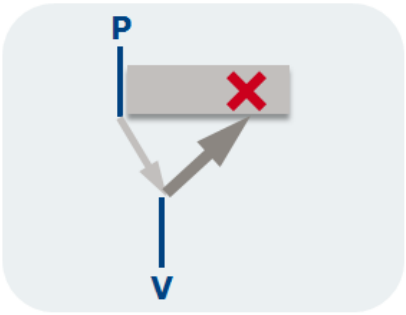
- Isolated premature ventricular contraction (PVC) which is the most common cause
- Too long programmed AV Delay (the nodal tissue is not refractory anymore when the device paces the ventricle)
- Failure of atrial sensing (undersensing) and atrial capture
- Myopotentials or interferences detected by the atrial lead
- VDD programming in a patient with a sinus rhythm slower than the programmed basic pacing rate

Example: Isolated premature ventricular contraction (PVC)

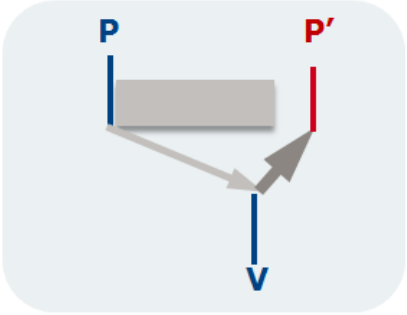


Start of PMT after an isolated premature ventricular contraction (PVC)

Example: Long AV delay

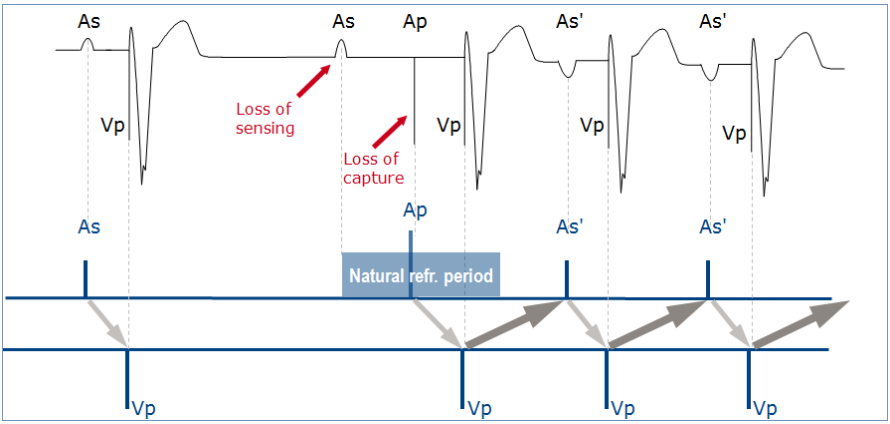


"Normal AV delay": it is unlikely for retrograde conduction (VA) to reach the atria before the end of the natural refractory periods.



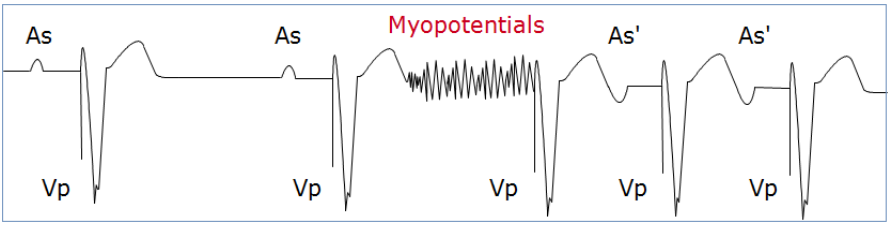
Long AV delay: it allows a recovery time for the nodo-hissian and atrial tissue to be depolarized retrogradely after the end of the natural refractory period. This could start a PMT.

Example: Atrial undersensing and loss of atrial capture



Start of PMT after atrial undersensing and loss of atrial capture

Example: Atrial oversensing (myopotentials)

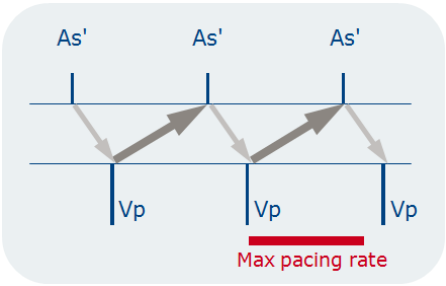


If myopotentials are sensed by the atrial lead, they will trigger an AV delay and ventricular pacing. Retrograde activation of the atrium is then possible since it is outside its natural refractory period.

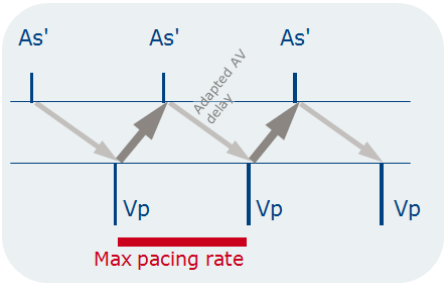
The heart rate during a PMT depends on:

- The retrograde conduction time (VA time) which is fast and stable at a given pacing rate
- The ongoing AV delay
- The maximum tracking pacing rate programmed

The PMT rate is equal or below the programmed Max tracking rate:



The PMT rate is lower than the programmed Max tracking rate since the VA time + AV delay time is longer than the Max pacing rate interval.



The PMT rate can NEVER be above the programmed Max tracking rate. The device automatically adapts the AV delay if necessary, so that the Max pacing rate is respected.

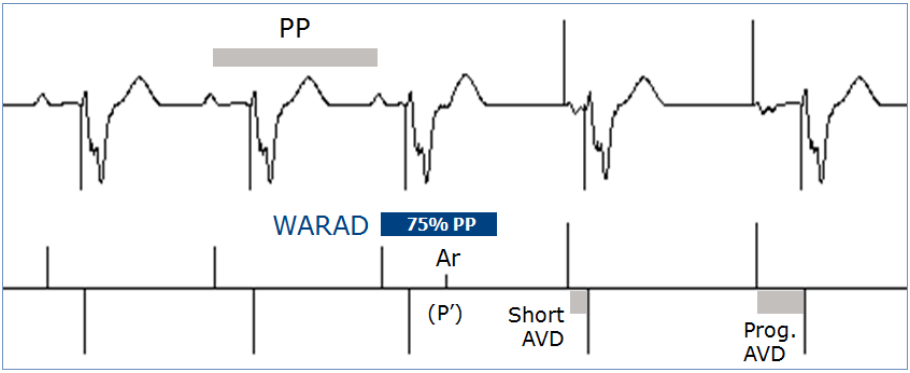
PMT PREVENTION

There are different options to prevent the occurrence of a PMT.

At MicroPort CRM, we have 2 protection periods (relative refractory periods) to prevent the start of a PMT:

Window of Atrial Rate Acceleleration Detection (WARAD)

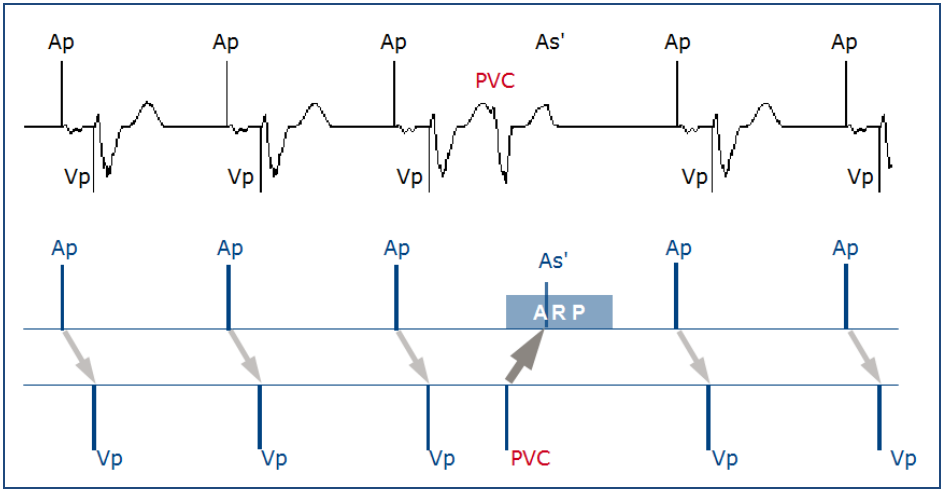
Embedded as a native feature in our dual-chamber devices, the WARAD is an efficient prevention against PMTs thanks to its dynamic functioning: the WARAD is started on any atrial sensed and paced event and its duration is adapted to the ongoing rhythm (more details in the *WARAD Tech Corner*). If a retrograde P wave occurs within the WARAD, it will not trigger an AV delay with ventricular pacing, which could generate a PMT. The P wave in the WARAD will be counted as a premature atrial contraction (PAC) by the device.



A retrograde P wave is detected within the WARAD and is therefore considered as a premature atrial contraction (marked Ar on the marker chain) by the device: no AV delay is triggered. The pacemaker will provide atrial pacing at the end of the VA interval (with a minimum of 500 ms between the retrograde P wave and atrial pacing), followed by an AV delay of 110 ms or the Exercise AV delay, whichever is shorter. This short AV delay will not cause retrograde conduction, which prevents a PMT from starting.

Atrial Refractory Period (ARP)

When a premature ventricular contraction (PVC) is detected, the device triggers a post-ventricular Atrial Refractory Period (ARP). The ARP is fixed at 500 ms (not programmable) and cannot be generated by more than 3 consecutive PVCs. The retrograde P wave (marked Ar on the marker chain, As' on the image below) is sensed inside the ARP and no AV delay is triggered. The atrium is then paced at the end of the VA interval, which can be prolonged to insure at least 500 ms interval between the retrograde P wave (As') and atrial pacing.



ARP is applied in the atrium for one cycle after any asynchronous ventricle (PVC) in order to avoid retrograde conduction: the P wave sensed inside the ARP (As') is "blocked", i.e. no AV delay is triggered and the PMT cannot start.

Other options to prevent the occurrence of a PMT are:

- Programming SafeR pacing mode (because it minimizes the ventricular pacing - more information in the *SafeR Tech Corner* article)
- Programming DDI. However this mode is not adapted for some patients, since there is no tracking of the P waves.
- Avoiding loss of AV synchrony:
  - By insuring a proper sensing and efficient pacing (with good margin)
  - By programming atrial bipolar sensing to avoid the detection of myopotentials or interferences by the atrial lead.

DESCRIPTION OF THE FUNCTIONING OF THE ANTI-PMT ALGORITHM

The following describes the 3 steps of the Anti-PMT algorithm to diagnose and terminate the PMT when it starts despite ARP and WARAD protection:

1. Suspicion (on 8 intervals)
2. Confirmation (2 or 4 cycles)
3. Termination (1 cycle)

1. PMT suspicion (8 intervals)

The detection of the PMT is based on the analysis of 8 consecutive ventricular cycles[1]:

- The 8 cycles must be with ventricular pacing (Vp) and atrial sensing (As): [Vp-As] intervals
- The [Vp-As] intervals (retrograde conduction time) are measured and must be shorter or equal to 470 ms: [Vp-As] intervals ≤ 470 ms (not programmable)
- The [Vp-As] intervals must be stable: d[Vp-As] ≤ 30 ms

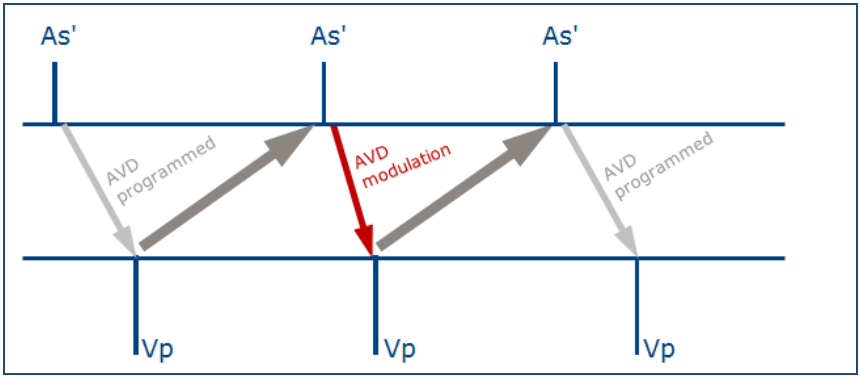
2. PMT confirmation: AV delay modulation (2 or 4 cycles)

Once a PMT is suspected, the device looks for confirmation ; the purpose is to discriminate a sinus rhythm from a PMT.

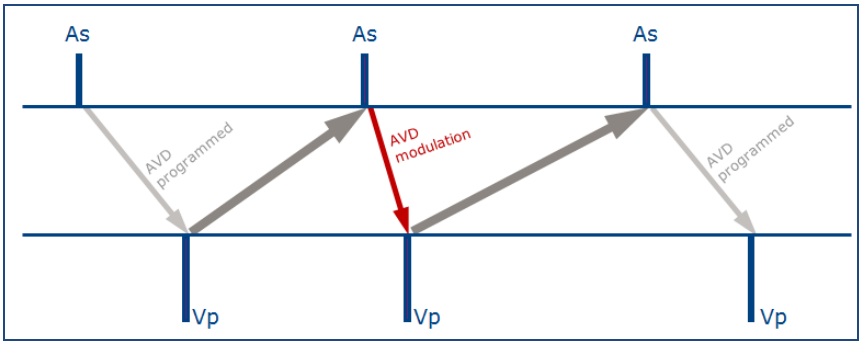
To make this distinction, the device modulates (increase or decrease) the AV delay and check the stability of the following [Vp-As] interval:

- If the [Vp-As] interval is stable after the modulation, the device confirms the PMT
- If the [Vp-As] interval is not stable after the modulation, the device confirms the sinus tachycardia.

[1] *Analysis of the last 8 consecutives ventricular cycles, sliding window*



PMT confirmation: After AV delay shortening (in red), the following [Vp-As] interval is stable: the device confirms the PMT



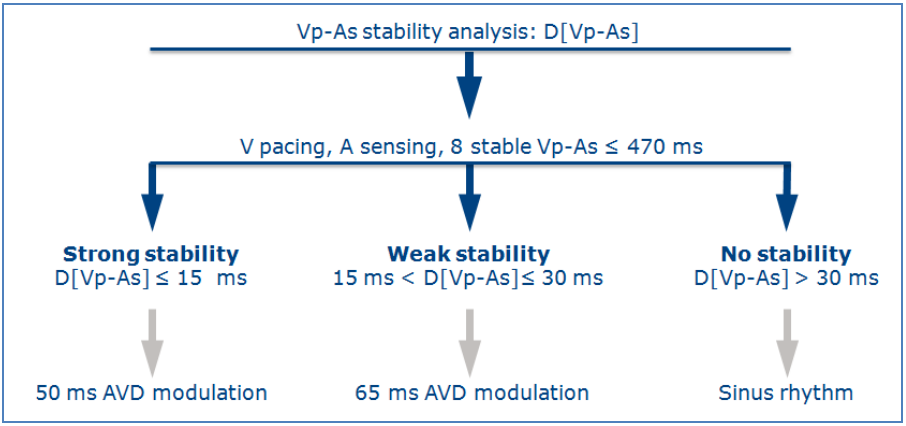
Sinus tachycardia confirmation: After AV delay shortening (in red), the following [Vp-As] interval is different from the previous ones: the device diagnoses a sinus tachycardia

Note:

In most of the cases, the AV delay modulation is a shortening of the AV delay, except if this would cause the ventricular cycle length to be less than the programmed minimum escape interval (*i.e.* pacing above the programmed Max pacing rate) or would cause an AV delay to be less than 30 ms. In these cases, the pacemaker increases the AV delay.

The AV delay modulation applied is:

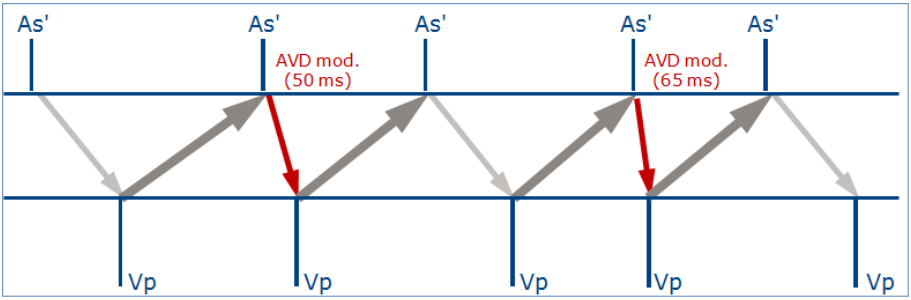
- 50 ms if the difference between the shortest and the longest [Vp-As] intervals from the 8 cycles in suspicion is ≤ 15 ms: this is the strong stability criterion.
- 65 ms if the difference between the shortest and the longest [Vp-As] intervals from the 8 cycles in suspicion is between 15 ms and 30 ms: this is the weak stability criterion.



PMT suspicion phase on 8 cycles: the device measures the retrograde conduction time (Vp-As) and enters in PMT suspicion if the Vp-As intervals are short (≤ 470 ms) and stable (+/- 30 ms)

Several cases may occur during the cycle which follows the AV delay modulation:

- The stability criterion is still met. In this case, the device confirms PMT and will proceed to convert it.
- The cycle that follows the modulation cycle, includes atrial pacing. This means that PMT was present and that shortening the AV delay successfully converted the PMT.
- The weak stability criterion is met, although before reducing the AV delay the strong criterion was met. Here the algorithm cannot reach a conclusion, therefore it applies a second modulation of the AV delay of 65 ms.

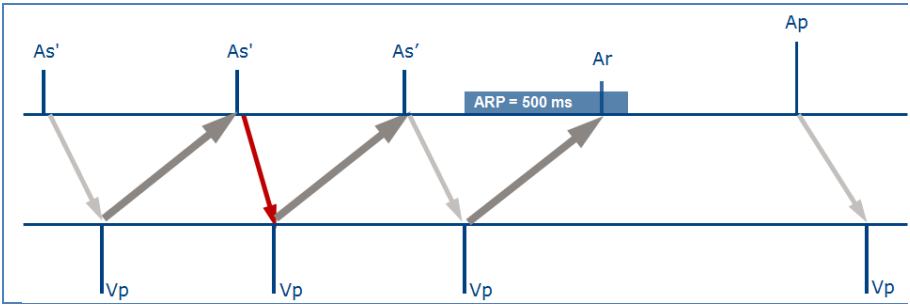


In this example the strong stability criterion is met, therefore a 50 ms AVD modulation is applied (first red arrow). On the following [Vp-As] interval the weak stability criterion is met, therefore the device cannot conclude: sinus rhythm or PMT? A second AVD modulation (now 65 ms) is applied (second red arrow) to conclude. The strong stability criterion is met: PMT is confirmed.

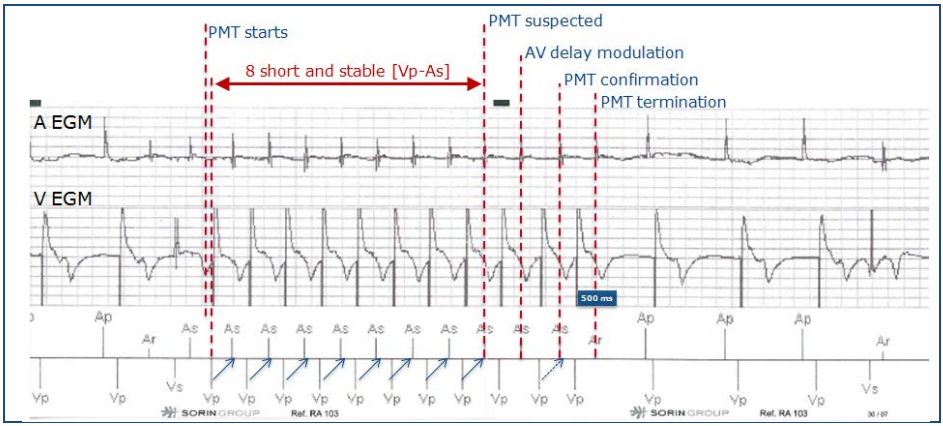
3. Termination (1 cycle)

Once the PMT has been confirmed, the device applies an atrial refractory period (ARP) of 500 ms when pacing the ventricle, so that the next retrograde P wave falls inside this ARP.

This refractory atrial event is not synchronised with the ventricle for one cycle (i.e. no AV delay is triggered) and the tachycardia is then terminated.



After a 50 ms AV delay shortening (in red), the stability criterion is still met (i.e. D[Vp-As] < 15 ms): the device confirms the PMT and applies the ARP on the next ventricular pacing to terminate the PMT.



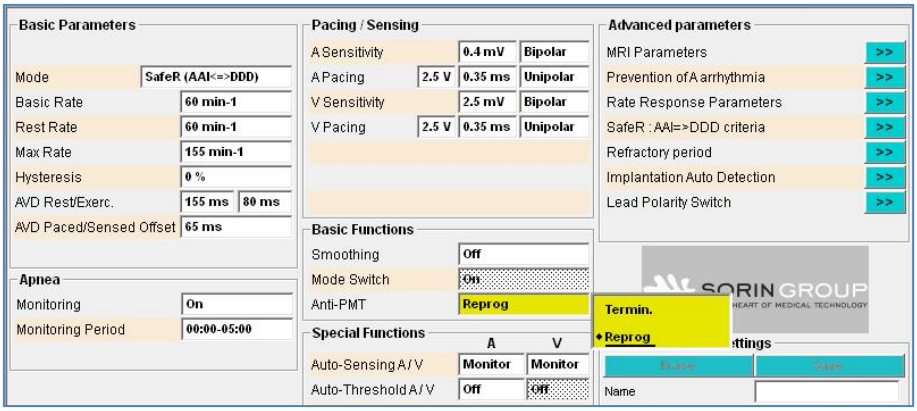
Diagnostic and termination of a PMT

PROGRAMMABLE PARAMETERS

The Anti-PMT algorithm can be programmed to:

- **Termin:** once the PMT has been confirmed, the device applies a 500 ms atrial refractory period (ARP) after the ventricular pacing to terminate the PMT.
- **Reprog:** once the PMT has been confirmed, the device applies a 500 ms atrial refractory period (ARP) after the ventricular pacing to terminate the PMT, and automatically decreases the Rest and Exercise AV delays by 15 ms in the event of recurrent PMTs[2], in order to limit the risk of new occurrences (due to long AV delays).

[2] Ten or more PMT episodes within 24 hours. The 24h interval is fixed and does not start on a PMT detection



Parameter screen: Anti-PMT programming on "Termin." Or "Reprog" (OFF can be programmed on Reply CRT-P)

Notes:

1. The algorithm cannot be programmed OFF (except on Reply CRT-P).
2. As soon as 10 PMTs are confirmed in the 24-hour interval, the algorithm reduces the Rest and Exercise AV delays by 15 ms steps, limited to 125 ms for the Rest AV delay and 80 ms for the Exercise AV delay, one step reduction after each confirmed PMT starting from the 10th PMT.

STUDIES AND RESULTS

1. Maillard L, Razani M, for the Chorus II Multicenter Study. Prevention of ELTS with an innovative fallback algorithm. PACE. 1995;18 (pt 2) Abstract 437:1213.

Refer to user's manual furnished with the device for complete instructions for use (www.microportmanuals.com).