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# Atrioventricular 1:1 tachycardia effectively terminated by antitachycardia pacing

What is your diagnosis?

- atrioventricular re-entrant tachycardia (AVRT), and
- atrioventricular nodal re-entrant tachycardia (AVNRT).

The diagnosis of VT is unlikely because the arrhythmia is initiated by an atrial premature beat and especially because the VA interval is so short. Supraventricular tachycardia with aberrancy is therefore likely. AT cannot be formally ruled out,

Table 1 Programmed	parameters		
Brady parameters			
DDD (AAI with VVI backu	lb)	40–115 bpm	
Pacing output	Atrial	2.5 V @ 0.4 ms	
	Ventricular	2.5 V @ 0.4 ms	
Sensitivity	Atrial	0.25 mV	
	Ventricular	0.4 mV	
Refractory periods	PVARP	240–280 ms	
	PVARP post PVC	400 ms	
	VRP	230–250 ms	
	A-Blank after V-pace	Smart	
	A-Blank after V-sense	Smart	
	V-Blank after A-pace	65 ms	
Tachy parameters			
VF zone		220 bpm (273 ms)	
Initial duration		2.5 s	
Redetection		1.0 s	
Quick Convert <sup>™</sup> ATP		On	
Shocks 1–8		41 J	
VTzone		170 bpm (353 ms)	
Initial duration		12 s	
Redetection		1 s	
SVT/VT discrimination enhancements		Onset/stability	
	Sudden onset	9%	
	Stability	20 ms	
AFib rate threshold		170 bpm	
ATP		3 bursts (10 pulses, increment 2 pulses, 84 % coupling, scan decrement 10 ms)	
Shocks 1–6		41 J	
ATP antitachycardia pacing, A atrial, AFib atrial fibrillation, PVARP postventricular atrial refractory			

period, *PVC* premature ventricular contraction, *SVT* supraventricular tachycardia, *V* ventricular, *VF* ventricular fibrillation, *VRP* ventricular refractory period, *VT* ventricular tachycardia

## **Case description**

A 44-year-old woman with idiopathic dilated cardiomyopathy and 40 % left ventricular ejection fraction (LVEF) received a dual-chamber Boston Scientific (Marlborough, MA, USA) Teligen 100 implantable cardioverter-defibrillator (ICD) for resuscitated sudden death. She presented at follow-up with palpitations. The episode shown in **Fig. 1 and 2** was retrieved from the device memory. The programmed parameters are shown in **Table 1**.

What is the most likely diagnosis and why?

How can the ICD behavior be explained?

#### Discussion

A tachycardia with sudden onset ("V Epsd Suddn" annotation) is initiated by an atrial premature beat ("AF 293") with a 1:1 AV relationship and short VA intervals (around 80 ms). The ratesense and far-field ventricular electrograms (EGMs) show a different morphology compared to the one during sinus rhythm. The arrhythmia progressively accelerates from around 330 ms to approximately 270 ms and is terminated by a burst antitachycardia pacing (ATP) sequence followed by a short sequence of atrial tachycardia and then sinus rhythm (AS 690 and thereafter). The differential diagnosis at this stage is

- ventricular tachycardia (VT),
- atrial tachycardia (AT),



Fig. 1 Electrogram of the arrhythmic episode

VT, A Rate: 182 min <sup>-</sup> ', V Rate: 180 min <sup>-</sup> '	
Detail	
VT Event Onset	
Avg A Rate	182 min <sup>-1</sup>
Avg V Rate	180 min <sup>-1</sup>
Detection	Onset/Stability
Onset	Percent
At Inhibit	
Stability	32 ms
V>A Rate	False
AFib	True
At V-Detect	
Avg A Rate	212 min <sup>-1</sup>
Avg V Rate	210 min <sup>-1</sup>
Rate Zone	VT
SRD Met	(False, Off)
ATP Timeout	False
Onset Intvl	(145 ms, Off)
Onset %	22 %

**Fig. 2** ▲ Details of the arrhythmic episode. *A* atrial, *ATP* antitachycardia pacing, *Avg* average, *Invl* interval, *SRD* sustained rate duration, *V* ventricular, *VT* ventricular tachycardia but the constant VA interval throughout the entire episode is unusual. There is no major "wobble" in rate during the tachycardia which would help determine whether the changes in V-V intervals precede or follow that of the A-A intervals (the former is seen in VT/AVNRT/ AVRT and the latter indicates AT). The ATP sequence resets the atrium ("AF 263" event), and therefore AT cannot be ruled out (interruption of the tachycardia without atrial reset would have ruled out this diagnosis, and VA dissociation without a change in atrial cycle length during ineffective ATP would have confirmed it). Ineffective ATP which resets the atrium is of diagnostic value, as the same criteria used in the electrophysiology laboratory may be applied to confirm AVNRT ("VAV" return sequence, stimulus-A minus V-A intervals <85 ms, postpacing interval-tachycardia cycle length>115 ms) [1]. AVRT is unlikely because of the short VA interval. Electrophysiological studies have shown that a VA interval measured from surface QRS onset to the high right atrial EGM of <95 ms (or to the earliest intracavitary atrial EGM of <70 ms) excludes AVRT [2] (and also excludes VT). The 80 ms VA interval measured from onset of the far-field ventricular shock EGM (which approximates the surface QRS complex) to the EGM of the right atrial lead positioned in the right atrial appendage (which approximates a high right atrial position) is less than the 95 ms cutoff previously described. AVNRT is therefore the most likely diagnosis. It

is important to note that measuring VA intervals from the intracavitary ventricular EGM may underestimate this interval because the signal of the right ventricular lead may be sensed late with respect to the onset of the QRS complex (e.g., in case of a supraventricular tachycardia with right bundle-branch block, or a leftsided VT). The patient also had true VT ( Fig. 3). Note the longer VA intervals during the ventricular premature beats preceding VT onset as well as during the arrhythmia (this may be a useful clue to determine if an intracavitary VA interval is "too short" in case a far-field shock EGM is not available, although coupling intervals should be taken into account due to decremental VA conduction). The patient was scheduled for an electrophysiological study, with induction of typical AVNRT which was treated by radiofrequency ablation.

Regarding device function in this Boston Scientific ICD, a ventricular episode is initiated ("V-Epsd" marker) when 8/10 RR intervals fall in the tachycardia zone (in this case, the first 8 consecutive intervals fall in the VT zone) with fulfilment of the onset criterion measured at 22 % ("Suddn" marker), which is more than the programmed threshold of 9%. Atrial sensed events during the tachycardia are labelled as "AF" because they are faster than the 170 bpm cut-off used to define the AFib rate threshold. A programmable duration timer (set to 12 s in this case) is then triggered. During the duration period,  $\geq 6/10$  intervals of the sliding 10-interval window need to fall in the tachycardia zone to keep incrementing the timer. In the present case, the episode slowed down with <6/10 fast intervals (probably due to a 2:1 response, which was documented on another occasion, or to intermittent ventricular undersensing) and initiated a 10 s "end of episode" timer. As 8/10 fast intervals were detected before the end of this timer, the episode continued and therapy was delivered at the end of a new 12 s duration timer. By design, EGM recordings are interrupted during prolonged episodes (shown as two vertical lines at the beginning of the second strip) at 10 s after the onset of the episode (counted from the third

fast beat of the episode) and displayed again during the 10 s prior to the end of the duration period ("V Dur" marker). The device then evaluates the stability criterion according to a weighted moving average. In the present case, the 15 first cycles are considered to be unstable and therefore therapy is withheld, until the 16<sup>th</sup> interval which is considered to be stable, with classification of the episode as a ventricular arrhythmia ("V-detect") and ATP is delivered with a burst of 10 cycles. The observant reader will have noticed a ventricular cycle with undersensing (in the middle of the second strip, preceding the VS 573 event). This led us to increase the programmed sensitivity. Furthermore, the atrial and ventricular events directly following ATP are labelled as "- -" and correspond to nonclassified beats, which immediately follow ATP or shocks in Boston Scientific ICDs

Inappropriate therapy may have been avoided had a more stringent stability criterion (i. e., less than 20 ms) been programmed, but this carries the risk of reducing sensitivity of VT detection. It is unlikely that Rhythm ID would have been more specific (especially with the default 96 % match threshold) as there appeared to be some aberrancy during tachycardia. AVNRT may be impossible for ICDs to discriminate from VTs when the intracavitary VA intervals are very short and the atrial event is not detected because it falls in the post ventricular atrial blanking period (PVAB) [3]. In this instance, the tachycardia will have a V > A-relationship and be classified as VT by dual-chamber algorithms in most devices, even if there is a morphology match. Medtronic (Minneapolis, MN, USA) ICDs have nominal setting of "partial PVAB" whereby atrial events during the PVAB are detected and labelled as "Ab" and used for by the PR Logic algorithm for rhythm discrimination (but not for timing of pacing). Junctional tachycardia with short VA intervals will therefore be correctly diagnosed as long as the 1:1 SVT criterion is activated (the default setting is "off"). Far-field R-wave oversensing will be identified in these instances by the patterns of atrial and ventricular events. The Boston Scientific "Smart" PVAB mode

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# H. Burri

# Atrioventricular 1:1 tachycardia effectively terminated by antitachycardia pacing. What is your diagnosis?

#### Abstract

This case describes a tachycardia with a 1:1 atrioventricular relationship that was effectively terminated with antitachycardia pacing by the implantable cardioverter defibrillator. The differential diagnosis and clues that allow the reader to establish the correct diagnosis are discussed. The case also serves to analyse technical features of Boston Scientific dual-chamber defibrillators.

#### Keywords

Atrioventricular nodal re-entrant tachycardia · Cardiomyopathy · Implantable cardioverter-defibrillator · Inappropriate therapy · VT/SVT discrimination

# Erfolgreiche Terminierung einer atrioventrikulären Tachykardie mit 1:1-Verhältnis durch antitachykarde Stimulation. Wie lautet die Diagnose?

#### Zusammenfassung

Dieser Fall stellt eine Tachykardie mit einem atrioventrikulären Verhältnis von 1:1 dar, die effektiv mit antitachykarder Stimulation durch einen implantierbaren Kardioverter-Defibrillator (ICD) beendet wurde. Die Differenzialdiagnose und Hinweise zur korrekten Beurteilung werden hier diskutiert. Dieser Fall eignet sich auch dazu, die Tachykardiediskriminierung bei Zweikammer-ICDs der Fa. Boston-Scientific zu erläutern.

#### **Schlüsselwörter**

AV-Knoten-Reentry-Tachykardie · Kardiomyopathie · Implantierbarer Kardioverter-Defibrillator · Inadäquate Therapie · VT/SVT-Diskriminierung



Fig. 3 < Nonsustained ventricular tachycardia (VT) episode in the same patient. Note the longer VA intervals compared to during AVNRT in **Fig. 1**. There is undersensing of a ventricular event (marked by \*) due to its relatively low amplitude, as well as its short coupling interval and the high amplitude of the preceding premature beat. These last two factors result in a low sensitivity at the timepoint of the undersensed event, due to the automatic sensing threshold of the implantable cardioverter-defibrillator





has a short blanking period of 15 ms followed by an automatic sensitivity adjustment. In Biotronik devices (Berlin, Germany), the PVAB (called "far-field protection after Vs") may be inactivated. Another possibility would be to inactivate the dual-chamber detection criteria (and rely on the morphology criterion to diagnose SVT, assuming that there is no aberrancy). Excellent reviews of ICD troubleshooting in the setting of AVNRT have been published [4, 5].

Prevalence of AVNRT in the ICD population has been reported to be as high as 3.5 %, which is higher than in the general population. This is probably

due to continuous rhythm monitoring and presence of atrioventricular nodal disease [6]. AVNRT may also be identified in cardiac resynchronization therapy (CRT) devices, even if the arrhythmia does not fall into VT zones, if the device stores ventricular sensing episodes (**•** Fig. 4).

In all instances of 1:1 AV tachycardia, device specialists should evaluate for presence of AVNRT by carefully analysing the following:

 the onset of arrhythmia (typically by an atrial premature beat with a prolonged AV interval),

- presence of short VA intervals (<100 ms), ideally measured from onset of the ventricular far-field shock EGM,
- variations in cycle lengths during tachycardia (with changes in V-V intervals preceding those of A-A intervals), and
- effect of ATP (cf. above).

This fully exploits ICDs, not only as lifesaving therapy, but also as valuable diagnostic tools.

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# Compliance with ethical guidelines

**Conflict of interest.** H. Burri has received institutional fellowship support and speaker fees from Biotronik, Boston Scientific, Medtronic, St-Jude Medical, and Sorin.

This article does not contain any studies with human participants or animals performed by any of the authors.

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