Atrial and Ventricular anti-Tachycardia Pacing as a Method of Rhythm Discrimination

ML Brown[1], R Yee[2], S Saba[3], A Abeyratne[1],
J Christensen[1], G Klein[2]

[1]Medtronic, Inc, Minneapolis, MN, USA
[2]London Health Sciences, London, Ontario, Canada
[3]University of Pittsburgh Medical Center, Pittsburgh, PA, USA

Abstract

Background: Inappropriate shock by implantable cardioverter defibrillators (ICD) remains a significant clinical problem. We evaluated a new algorithm for discriminating 1:1 SVT and VT, based on the response to atrial (A) and ventricular (V) anti-tachycardia pacing (ATP). ***Methods:*** *64 pts (age: 46 ± 16 yrs, 34 male, LVEF: 54 ± 11%) undergoing EP testing or SVT ablation underwent AATP and VATP through a customized external Marquis ICD once tachycardia was induced. The response to A or V ATP was classified as AT or non-AT according to predetermined criteria.* ***Results:*** *The V ATP algorithm correctly identified AT with a sensitivity of 70% (53%-82%) and specificity of 77% (61%-88%). The A ATP algorithm correctly identified AT with a sensitivity of 96% (84%-99%) and specificity of 91% (67%-98%).* ***Conclusions:*** *Analysis of cross chamber response patterns during and after ATP can successfully discriminate tachycardia mechanism and prevent inappropriate ICD shocks.*

1.   Introduction

Implantable Cardioverter Defibrillators (ICDs) discriminate treatable (VT/VF) from non-treatable (SVT) tachycardias on the basis of passive measures derived from intracardiac electrograms. As ICDs have advanced, more sophisticated algorithms have been developed to supplement older basic methods. Dual and triple chamber ICDs have become common and provide more intracardiac signals from which to derive measures. Use of these additional signals and more sophisticated measures have improved detection performance, but these improvements are masked by changes in the ICD population, an increasingly healthier group as indications for implantation expand. As a result, performance evaluations of ICDs still indicate at least 10% of ICD therapies are inappropriate. One must be cautious in reviewing these performance evaluations because the manner in which devices are programmed and the manner in which the data are screened can have a dramatic influence on the reported results.

As ICD technology improves, more sophisticated passive detection criteria will be made available. However, certain rhythms are difficult to discriminate, even by human experts, solely on the basis of passive observation of EGM signals. Another approach to SVT/VT discrimination is to use a technique commonly used by electrophysiologists in the EP laboratory, namely that of providing pacing stimuli during tachycardia and evaluating the physiologic response during and soon after pacing.

The evaluation of inappropriate detections from the GEM DR clinical trial [1] showed that one of the major causes of inappropriate VT/VF detections for PR Logic were 1:1 SVTs. Discriminating 1:1 SVT from VT with 1:1 retrograde conduction on the basis of interval pattern is difficult because the AV patterns and rates of the rhythms overlap. Discrimination techniques that do not depend on AV pattern or that use the pattern in an adaptive manner have been developed, but there continues to be a need to improve discrimination of 1:1 rhythms. Wathen reported at HRS 2004 [2], that over 50% of 1:1 SVTs that were overdetected by dual chamber ICDs were terminated or slowed outside the tachycardia detection zone following delivery of ATP. This suggests that there may be a benefit in delivering some ATP to 1:1 tachycardias in an attempt to terminate them and subsequently to classify the rhythm as VT/SVT should the tachycardia not terminate. We evaluated a new algorithm for discriminating 1:1 SVT and VT based on the response to atrial and ventricular burst pacing sequences.

2.   Methods

This study was a feasibility study designed to evaluate

different potential pacing protocols for use in discriminating supraventricular from ventricular tachyarrhythmias. Patients were enrolled at two centers.

In this study we evaluated pacing trains of three different lengths 5, 10 and 15. We chose pacing cycle lengths that are effective at terminating tachyarrhythmia with minimal incidence of proarrhythmia, 81 and 88% of the tachycardia cycle length. While the primary objective of the study was to evaluate use of the physiologic response to pacing for diagnostic purposes, termination of tachycardia is also an important outcome of ATP. Terminations are included in the study results. Specific pacing sequences were repeated two times to determine whether responses were consistent.

This study was an acute clinical study using an ICD-in-a-box. The ICD used for this study was a Marquis DR. Only the pace/sense signals were made available external to the box housing the ICD. The study was performed during EP studies, ablation procedures or ICD implantation. During these procedures, tachyarrhythmias were induced, consistent with normal clinical practice. Once the tachyarrhythmia was induced, the ICD detected and delivered ATP-like pacing sequences in either the atrium or the ventricle according to the protocol. The tachycardia, pacing sequences and responses were recorded within an episode record of the ICD and additionally were also recorded on an EP recording system. The Marquis DR episode record can store up to 3 minutes of EGM which is sufficient to record all pacing sequences if the tachyarrhythmia is somewhat fast (<450 ms cycle time).

All patients undergoing EP study, ablation or ICD implantation were eligible for enrollment in this study. The ICD was programmed first with the standard Vision software. A second programmer running custom research software was then used to modify the therapies that were to be delivered to the atrium. The research software was also used to program the atrial pacing output.

Detection programming for this study was designed to detect and deliver ATP sequences for tachyarrhythmias with ventricular intervals in the range of 240-500 ms. No shock could be delivered to the patient because the high voltage outputs were not externalized from the boxed ICD. There were four different ATP sequences used for the study to vary the order of delivery and rate of the ATP. The sequences were numbered 1-4 and each successive patient received the next therapy sequence.

The V ATP dynamic discrimination algorithm was prospectively designed to recognize atrial tachycardia (AT) with high specificity to reduce or eliminate inappropriate therapy for 1:1 SVT while maintaining sensitivity for VT at or near 100%. Whenever there was an ambiguous response, the rhythm was classified as VT to maintain maximum sensitivity. It was expected that

during atrial tachycardia (or sinus tachycardia) that the atrial rate would be unaffected by ventricular pacing. During VT with 1:1 retrograde conduction, it was expected that the atrial rate would accelerate to the ventricular pacing rate unless the V pacing interval was shorter than the VA Wenckebach interval. AVNRT was expected to exhibit an atrial response similar to VT and thus would be incorrectly classified as VT. This would reduce detection specificity, but would not affect VT sensitivity. Historically, the incidence of AVNRT in the ICD population has been low, but results from PainFREE Rx II suggest that it may have an increasing incidence now that EP study prior to ICD implantation is not often warranted. It was expected that AVNRT would be easily terminated by ATP regardless of the chamber in which it was delivered.

Three atrial response patterns during a burst of ventricular ATP were defined and used for classification [3]. The atrial cycle length (ACL) may be unchanged during V ATP (Type 1), the ACL may show significant variation during V ATP (Type 2), or the ACL may accelerate to the V ATP cycle length (Type 3).
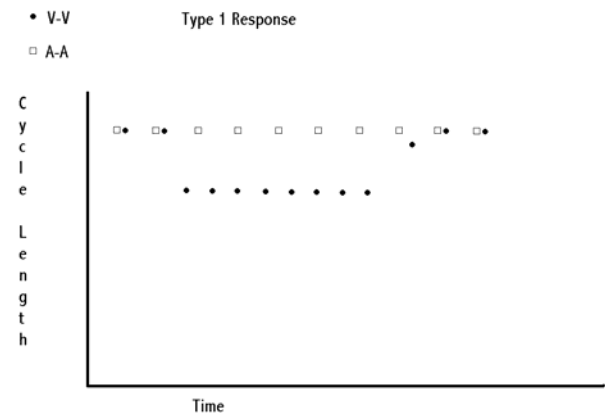

Figure 1: Type 1 response indicates complete dissociation of A from V, is consistent with an AT mechanism, and would not be expected during a non-AT. One non-AT SVT that could illicit a type 1 response is AVNRT with retrograde block in or below a lower common pathway such that VA dissociation can occur with V pacing. Historically, ICD patients have exhibited a low incidence of AVNRT. Over-detection of AVNRT should be rare and when it is over-detected, it will often be terminated by a single ATP sequence.
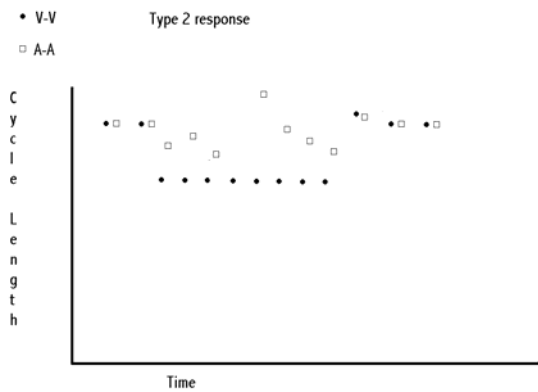
Figure 2: Type 2 response indicates a variable VA conduction with Wenckebach or variable VA block and does not discriminate between an AT mechanism or a non-AT mechanism. A default diagnosis of non-AT mechanism is made in this case so that VT detection sensitivity will not be sacrificed.
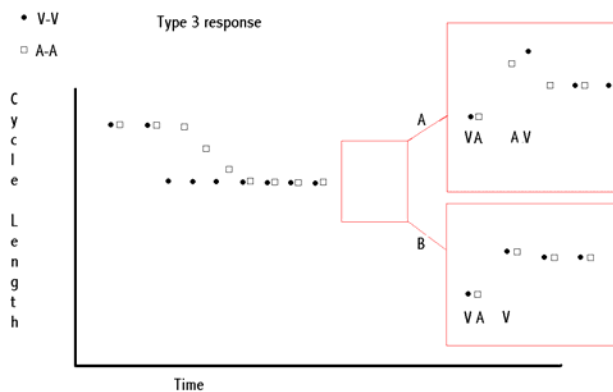

Figure 3: Type 3 response indicates atrial entrainment by V ATP. By itself this response does not discriminate AT from non-AT mechanism. However the response after entrainment does give evidence for tachycardia mechanism. A VAAV response at the end of ATP is diagnostic of an AT mechanism (Type 3A) whereas a VAV or VVA response is diagnostic of a non-AT mechanism (Type 3B).

An algorithm was constructed to systematically define the atrial response to V ATP as one of the above types. When an A and V are within 50 ms, the pair of sensed events in classified as H and the rhythm classified as AVNRT.

The A ATP dynamic discrimination algorithm operates like the V ATP algorithm, but with the A and V reversed. Thus, for instance, when the ventricular intervals are unaffected by atrial ATP, the response is classified as type 1 and the rhythm is classified as VT. As before, type 2 response is non-diagnostic, so default classification is VT. A 3A response, ie, A pacing entrains V, with an

ApVVA response at the end of AT, is diagnostic for VT and 3B response is diagnostic for SVT.

3. Results

Sixty-four patients (30 F) were enrolled at two centers. Mean age was 46 +/- 16 years, 11 (20%) had a history of coronary artery disease and the mean left ventricular ejection fraction was 0.54 +/- 0.11. These baseline characteristics are younger with better cardiac function than a typical ICD population because most patients enrolled in the study were undergoing EP study for suspected SVT or SVT ablation.

Fifty-two patients had 120 episodes induced (76 AVNRT, 34 AT, 10 VT) which allowed 534 ATP sequences to be delivered. This was a much higher incidence of AVNRT than is typical of an ICD population, but is typical of an SVT ablation population.

The discrimination performance of the A ATP and V ATP methods were compared in two manners. First, we compared AT sensitivity and specificity for A ATP and V ATP methods. For these computations, AVNRT was classified as non-AT and thus detection of one of these as AT was counted against AT specificity. The GEE-adjusted AT-sensitivity estimates and 95% confidence intervals by ATP chamber were: A ATP (103/107) = 96% (84% to 99%) and V ATP (111/165) = 70% (53% to 82%). The GEE-adjusted AT-specificity estimates and 95% confidence intervals by ATP chamber were: A ATP (35/38) = 91% (67% to 98%) and V ATP (100/140) = 77% (61% to 88%). AVNRT was classified as AT 19 times by the V ATP method.

We also compared the VT sensitivity and specificity for the A ATP and V ATP methods. For these computations, AVNRT is classified as non-VT and thus detection of one of these as VT is counted against VT specificity. The GEE-adjusted VT-sensitivity estimates and 95% confidence intervals by ATP chamber: V ATP (5/16) = 75% (24% to 97%). No A ATP was delivered into VT. The GEE-adjusted VT-specificity estimates and 95% confidence intervals by ATP chamber: A ATP (106/145) = 67% (47% to 83%) and V ATP (140/289) = 49% (37% to 61%).

The table below provides a comparison of termination efficacy of different ATP modalities. The 81% ATP cycle length was significantly better than 88% for terminating both SVT and VT. A burst of 10 pulses was significantly better for terminating tachycardias than 5 pulses. Visual assessment of electrogram strips suggested that a train of five pulses was insufficient to capture the entire ventricle so in general will be unable to penetrate the excitable gap.

	AT n = 278	AVNRT n = 235	VT n = 21
Tachy CL (ms)	491 ± 59	366 ± 70*	302 ± 55*
% Termination	2%	36%	30%
% Termination by ATP Chamber			
• A	--	56%	
• V		32%	44%
% Termination by ATP CL			
• 81%†	--	54%	65%
• 88%†		26%	0%
% Termination by ATP # of Pulses			
• 5 pulses**	--	16%	16%
• 10 pulses**		45%	42%
• 15 pulses		26%	22%

Table 1: All % termination estimates have been GEE-adjusted for the effect of multiple observations for same patient
†Adjusted p-value = 0.018, ** Adjusted p-value=0.0072

4. Discussion and conclusions

In this study, we evaluated an algorithm designed to discriminate 1:1 tachycardias. Overdetection of 1:1 SVT is one of the leading causes of inappropriate therapy among dual chamber ICDs. Defibrillator detection algorithms currently use passive means, intervals and electrogram morphology, to evaluate rhythm truth. In this study, we evaluated an algorithm that uses active means, pace stimulation, to better discriminate these 1:1 tachycardias.

The vast majority of the time, a 1:1 tachycardia in an ambulatory ICD patient is sinus tachycardia or atrial tachycardia. VT with 1:1 retrograde conduction represents about 5-10% of all VT episodes, typically found in fewer than 15% of patients with ICDs. In the past, AVNRT has been relatively rare because once observed these rhythms are easily ablated. AVNRT was often identified ablated during elecrophysiologic study which was routinely performed prior to implantable cardioverter defibrillator implantation.. It has been hypothesized that there may be a higher incidence of AVNRT now because patients no longer routinely have an electrophysiologic study prior to implant.

In this study, nearly two-thirds of the induced episodes were AVNRT. This unusually high rate of AVNRT is the result of a high rate of enrollment of SVT patients undergoing ablation. The relatively low rate of enrollment of ICD patients in this study is the result of the change in practice away from requiring electrophysiologic study prior to ICD implantation because of expanded indications for ICD. While enrollment during ICD implantation was allowed, the yield was low perhaps because the implant procedure is more time-sensitive. Unfortunately, this skewed distribution of episodes and relatively small number of VT episodes makes it difficult to draw strong conclusions from these results.

Results from this acute feasibility study do not provide conclusive answers regarding this novel approach to ICD detection. While the results are promising with many terminations and good discrimination for those rhythms that did not terminate, the patient population and thus rhythms evaluated in this study are not representative of an ICD population.

Burst pacing, whether delivered from the atrium or the ventricle, as a means of discriminating 1:1 tachycardias shows some promise, but algorithm improvements will be needed before ambulatory use is warranted. Evaluation of the algorithm on a more representative population of patients and rhythms is also needed.

References

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Address for correspondence

Mark L. Brown, PhD
Medtronic, Inc
8200 Coral Sea Street
MS MVN41
Moundsview, MN 55112
E-mail address Mark.L.Brown@medtronic.com