The Implantable Dual-Chamber Cardioverter/Defibrillator: Algorithms and Technology for Discrimination of Supraventricular Tachyarrhythmias

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Summary

The algorithm for dual chamber VT/SVT discrimination used in the Biotronik Phylax AV™ is discussed. This algorithm also allows for the detection of concurrent VT during an episode of SVT.

Introduction

The Implantable Cardioverter/Defibrillator (ICD) has proved itself to be a valuable tool in the treatment of Ventricular Tachycardia (VT) and Ventricular Fibrillation (VF). With the availability of stored electrograms, it has become possible to analyze the cause of the therapy initiated by the device. This analysis suggests that a significant fraction of delivered therapies were in response to tachyarrhythmia of a supraventricular nature [1,2]. Since the foci of these SupraVentricular Tachycardia (SVT) episodes are not in the ventricle, ventricular based therapies such as Anti-Tachycardia Pacing (ATP) is not only ineffective, but may also induce episodes of VT. Since most therapies are programmed to ultimately deliver CardioVersion (CV) shocks, this will typically result in successful termination of these episodes of SVT.

From a hemodynamic point of view, an episode of SVT, even one conduction to the ventricle at a 1:1 ratio, is believed to be better tolerated than an episode of VT. Thus, a less painful therapy strategy for the patient is not to immediately terminate an episode of SVT, but to let it run its course, as long as there is no concurrent episode of VT.

With the advent of the dual chamber ICD [3,4] providing both atrial and ventricular sensing, it is now possible to reliably differentiate SVT episodes from VT episodes, and further more to detect VT episodes during SVT episodes.

In this article, we will discuss the algorithm that been implemented in a dual chamber ICD with VT/SVT discrimination (Biotronik Phylax AV™).

Method

The basic principle of the algorithm is that the chamber with the higher rate is the source of the tachyarrhythmia. The resulting discrimination is illustrated in Figure 1.

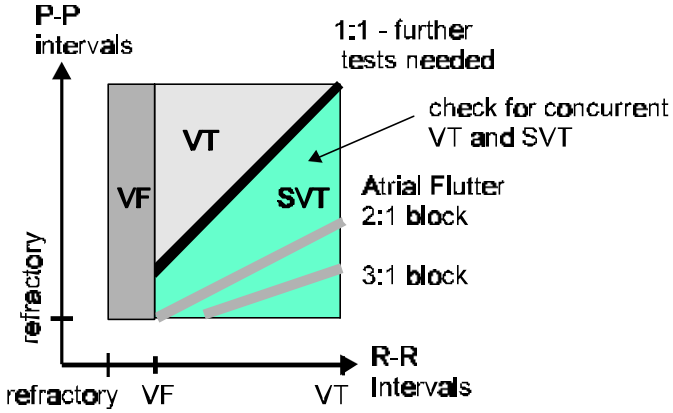

Figure 1. Overview of VT/SVT discrimination algorithm

The algorithm gives VF detection top priority. Thus, any ventricular rate above the VF limit will be treated with defibrillation therapies.

In the VT zone, the discrimination algorithm is applied. If the ventricular rate is faster than the atrial rate, then the tachyarrhythmia is declared a VT and the appropriate VT therapies are delivered. No further test is needed.

In the region where the atrial rate is higher than the ventricular rate, that the algorithm will classify as SVT. However, a concurrent episode of VT may occur independently or as a result of the SVT episode. Thus, while ventricular therapy is withheld appropriately, it is imperative that the ventricular rhythm be constantly monitored to detect occurrences of concurrent VT.

There are some instances where SVT can be declared with certainty. This is the case of atrial flutter with 2:1 or 3:1 conduction block. The requirements in this scenario are that the rates be stable and there is an integer ratio relationship between the two rates.

The detection of a concurrent VT in the SVT region of Figure 1, as with single chamber ICDs, is accomplished by monitoring the stability of the ventricular rhythm. Except for the atrial flutter cases, if the ventricular rhythm is stable, then a concurrent episode of VT is declared.

In the case where the rates in the two chambers are the same, the algorithm undertakes further tests to detect the source of the tachyarrhythmia. The goal being to differentiate between Sinus Tachycardia (ST), AV nodal tachycardia, low rate atrial tachycardia with 1:1 conduction and VT with retrograde conduction.

- Stability is again used in this 1:1 rate case. If the ventricular rhythm is stable while the atrial rhythm is not, then VT is declared.
- Using P-R interval regularity, we can differentiate between events which are conducted from the atrium to the ventricle.
- Regular P-R intervals can be detected for all the tachyarrhythmias mentioned above. In this case, sudden onset is used in a limited fashion to discriminate between ST and other tachyarrhythmias. VT therapy is delivered if the onset criterion is met.

Results

The algorithm discussed was implemented in the Biotronik Phylax AV™. Animal testing were conducted. Nine human implants (7M/2F, mean age 49.6 ±12.9) of the Phylax AV were performed over a period of one year (starting in April 1996). VT was correctly discriminated from atrial flutter and atrial fibrillation in all cases. Episodes of atrial tachyarrhythmia have been reported by the patients without any therapy being delivered. These were confirmed with the Holter records.

During intra-operative tests, atrial flutter and atrial fibrillation episodes were induced in the patients using rapid atrial pacing. With the dual chamber

discrimination algorithm turned on, no therapy was delivered. Detection reliability was verified by turning the dual chamber algorithm off and using a simple rate based single chamber algorithm that resulted in delivery of therapy. An example of a dual chamber IEGM recorded with the dual chamber discrimination algorithm turned off is illustrated in Figure 2. No therapy was delivered during this episode of atrial flutter with the dual chamber discrimination algorithm turned on.

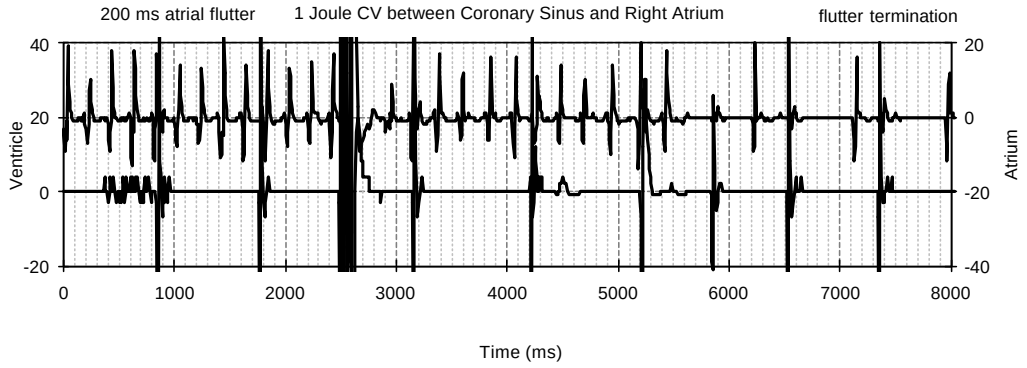

Figure 2. Atrial Flutter Detected with Single Chamber Algorithm

Figures 3a-c illustrate a concurrent episode of VT during an episode of SVT in a dog model with the dual chamber discrimination algorithm active. This data is from the stored IEGM record, which is over 35 seconds long. 7 such episodes can be stored. No therapy is delivered during the SVT-only episode. Therapy is in response to the VT episode starting at 18.8 s.

Discussion and Conclusion

Extensive testing using an animal model was performed with this AV discrimination algorithm and the results confirm excellent discrimination capability. Jenkins [5] reported that, with a simpler algorithm, better than 83% accuracy for VT/SVT classification was achieved. From our experience with the Ann Arbor Electrogram data base and our own experience with animal models and actual patients, we expect an even higher success rate.

The 1:1 atrial:ventricular rate case remains a difficult scenario for classification algorithms. With any passive detection algorithm, one will never be able to get close to 100% successful discrimination. An active discrimination algorithm using pacing may improve the classification. This will be discussed in a forthcoming paper.

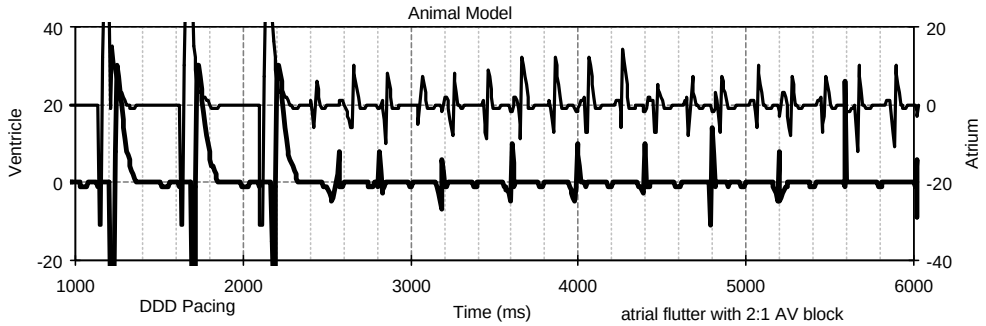

Fig. 3a. Beginning of induced atrial flutter episode. A; 200 ms, V: 400 ms.

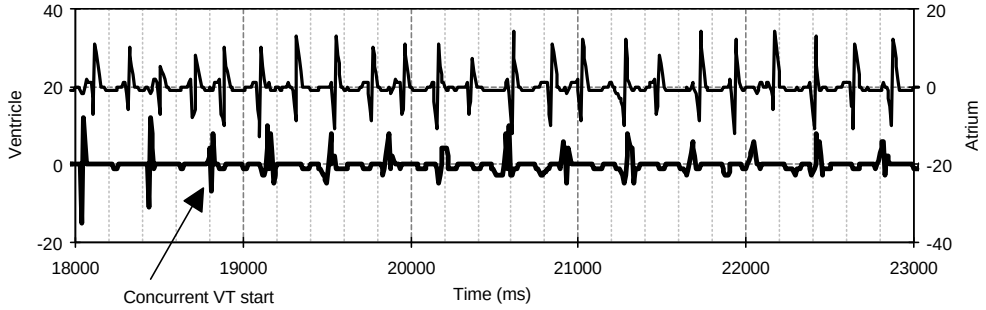

Fig. 3b. VT of 320 ms starts at about 18.8 seconds.

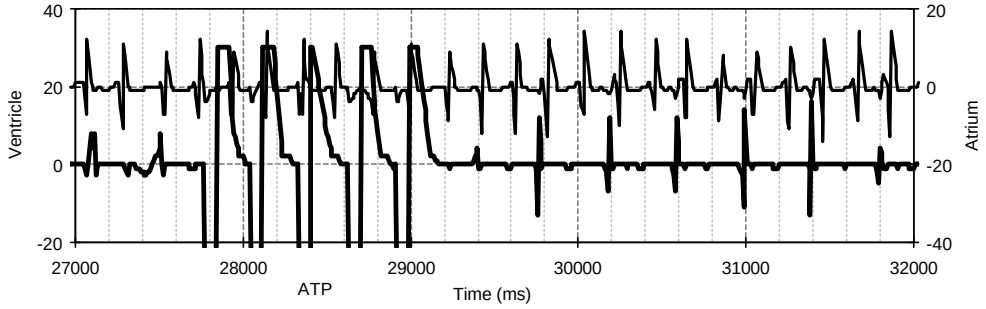

Fig. 3c. ATP Therapy following detection of concurrent VT

Figures 3. Concurrent SVT and VT - Dog model

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