Active Discrimination of the Origin of Tachyarrhythmias in a Dual Chamber ICD

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Summary

The discrimination of the origin of tachyarrhythmias with equal atrial and ventricular rates still is a challenge for currently available algorithms. While one solution could be to increase the number of rules for the interpretation of the rhythm, here, a different method is proposed: It is hypothesized that the application of ventricular extrastimuli will lead to different atrial responses during ventricular tachycardia (VT) compared to supraventricular tachycardia (SVT). This active discrimination method was investigated during dual chamber ICD implantation (13 patients) and during electrophysiologic (EP) examination (25 patients). In the EP study the atrial intervals shortened by 21.2 ± 13 ms ($p < 0.009$), if the extrastimuli were applied during ventricular tachycardia. During supraventricular tachycardia, they remained unchanged (1.36 ± 1.16 ms). During ICD implantation, 20 clinical SVT and VT episodes were induced; another 22 VT episodes were simulated by pacing at the rate of the patient's intrinsic tachycardia. In the clinical episodes, sensitivity and specificity for VT detection assumed values of 100 and 88% respectively, whereas both specificity and sensitivity were 100% in the simulated episodes. The results show that the application of ventricular extrastimuli is safe - no proarrhythmia was observed - and efficient for atrioventricular discrimination. The method will be validated in a prospective ICD follow-up study.

Key Words

Ventricular fibrillation, defibrillation, atrioventricular discrimination, dual chamber defibrillator

Introduction

It is generally accepted that one third of all implantable cardioverter defibrillator (ICD) patients may benefit from DDD pacing and atrioventricular (AV) discrimination. The incidence of inappropriate shock releases has been reported to reach values of up to 41% [1-3]. These figures may help to understand why the availability of ICDs with atrial pacing and sensing capabilities has led to an overwhelming response in the beginning.

However, after the first years of clinical experience this enthusiasm has given place to a more realistic appreciation of the complexity of AV discrimination. The analysis of equal atrial and ventricular rates still remains a challenge for any discrimination algorithm. The complex interaction between atrial and ventricular activity in the genesis and perpetuation of arrhythmias may lead to a variety of rhythm patterns that are not amenable to simple rules. One possible direction of development has been to increase the number of criteria and to base these criteria on ever more sophisticated parameter analyses. Yet, the addition of new rules may cause new problems through the interaction with those which already exist. It may therefore be helpful to attempt to simplify the situation by providing well-defined boundary conditions. In terms of fact this means to set the rate in one chamber by the application of appropriate pacing impulses and to analyze the resulting activity of the other chamber.

In the following, clinical results with the dual chamber ICD PHYLAX AV (BIOTRONIK) are reported (confer also [6]). During intraoperative device testing, a new algorithm for active discrimination between ventricular and supraventricular tachyarrhythmias has been investigated which follows the strategy outlined above.

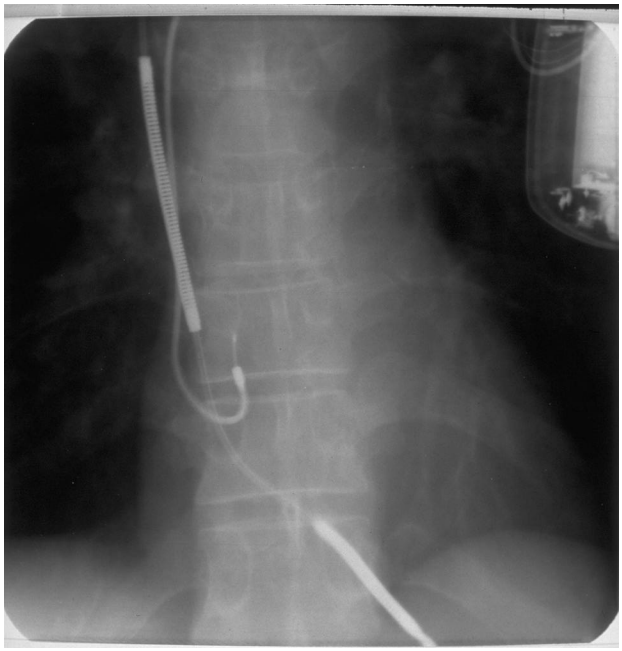

Figure 1. X-ray of an implanted PHYLAX AV.

Materials and Methods

Algorithm

In general, there are two different possibilities for the implementation of an active discrimination algorithm. On the one hand, the hypothesis of sinus tachycardia may be tested using premature atrial extrastimuli [4, 5]. On the other hand, premature ventricular extrastimuli (PVES) allow to probe the hypothesis of retrograde conduction from the ventricle to the atrium to test for ventricular tachycardia. If the origin of the tachycardia is in the atrium with a 1:1 conduction ratio to the ventricle and an extrastimulus is applied in the atrium, it is expected that the corresponding R-R interval will be modified when compared to the previous one. If the tachyarrhythmia is of ventricular origin, there should be no great discrepancy in R-R intervals since there is a negligible probability that the pulse could reach excitable tissue in the ventricle due to still refractory ventricular tissue.

Premature ventricular extrastimuli are expected to provide suitable means in answering the question whether the detected tachycardia is of ventricular origin and whether the high atrial rate is due to retrograde conduction of the ventricular events. In such a case, a PVES is likely to propagate toward the AV node and infiltrate the atrium, where this particular event is promptly detected. Then, the current P-P interval is different from the previous one, indicating VT. If a supraventricular tachycardia (SVT) is present, it is most likely that the retrograde propagation of the PVES will be blocked in the AV node or in the atrium, at the latest, by antegrade conduction of the atrial events. As a consequence, there is no variation in the respective P-P intervals. In this event, a non-VT is diagnosed; no ventricular therapy is delivered.

Preliminary tests revealed that premature atrial extrastimuli need a very long burst for ventricular capture during an SVT episode. This is due to the high probability that extrastimuli are blocked by refractory atrial substrate. Additionally, long burst duration may be dangerous for the patient since VT can be initiated during an ongoing SVT. Consequently, our approach has focused on delivering premature ventricular extrastimuli.

Patient data and devices

Our patient group comprises 18 patients (16 male/2 female, mean age 56 ± 8 y). Indication for implantation of a dual chamber defibrillator was ventricular tachycardia and atrial fibrillation or flutter in 33%, ventricular tachycardia and fibrillation in combination with atrial flutter and sick sinus syndrome in 17%, ventricular tachycardia and fibrillation combined with atrial fibrillation or flutter in 25%, ventricular tachycardia, atrial fibrillation and IInd degree AV block in 17%, as well as ventricular tachycardia and fibrillation combined with supraventricular tachycardia in 8% of patients. The underlying cardiac diseases were arrhythmogenic right ventricular dysplasia (17%), congestive heart failure (65%), mitral valve replacement (6%), idiopathic VT (6%), and none (6%).

A lead with two shock coils (right ventricle and superior vena cava) and ventricular pacing sensing was used in 9 patients (SL-ICD, BIOTRONIK), a lead with a single right ventricular shock coil was implanted in 9 patients (SPS and Kainox, BIOTRONIK). For atrial pacing and sensing standard active or passive fixation leads were used (YP 53-BP, RX 53-BP, SX 53-BP, BIOTRONIK). Figure 1 shows an example of an implanted PHYLAX AV.

The algorithm was tested in 13 out of the 18 patients using a prototype dual chamber ICD with means for active atrioventricular discrimination and automatic atrial therapy delivery. In another 25 patients, the per-

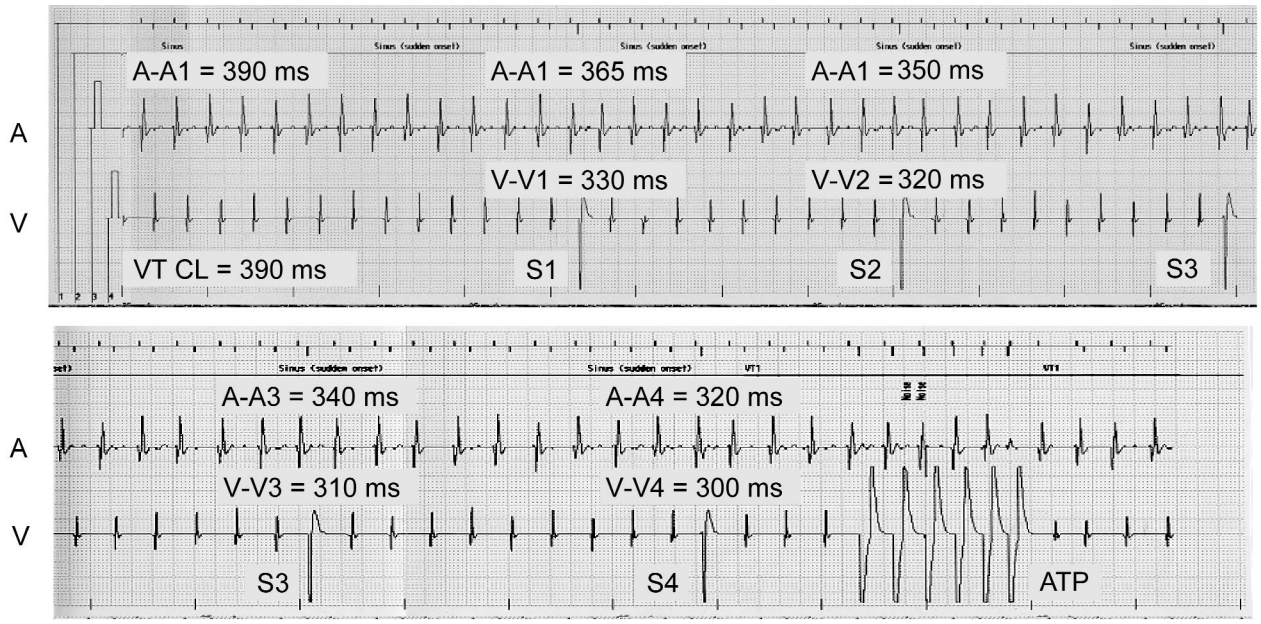

Figure 2. Example for detection of a ventricular tachycardia by the active discrimination algorithm. Detection success is indicated by the antitachycardic "marker" paces.

formance of the algorithm was investigated during otherwise routine invasive electrophysiologic examination.

Results

Dual chamber ICD implantation

Mean signal amplitudes were 3.2 ± 1.7 mV in the atrium and 14.5 ± 5.2 mV in the ventricle. Mean defibrillation threshold (DFT) was 8.5 ± 3.8 J (right ventricular shock coil versus active ICD housing).

During intraoperative testing of the active discrimination algorithm, 22 episodes of clinical ventricular or supraventricular tachycardia were induced. Another 20 VT episodes was simulated by stimulating the right ventricle at a cycle length identical to the patient's intrinisic VT cycle lenght. For comparison, the atrium was stimulated at the same cycle length in order to simulate a supraventricular tachycardia. For all simulated episodes an additional lead and an external threshold analyzer were used. Figure 2 and Figure 3 show examples for ventricular and supraventricular tachycardias respectively. The clinical episodes were detected by the algorithm with a VT sensitivity of 100% and a specificity of 88%. For the paced episodes, both sensitivity and specificity were 100%. In two patients, a device with active discrimination was implanted.

Electrophysiologic examination

As described in the Methods section, ventricular extrastimuli were applied during tachycardic rhythms with equal atrial and ventricular rates in a variety of situations including the Wolff-Parkinson-White (WPW) preexcitation syndrome: In 7/25 patients, the investigations were carried out during VT with 1:1 conduction, in 4/25 patients during AV nodal reentry tachycardia and paced VT, in 9/25 patients during drug induced sinus tachycardia and paced VT, and in the remaining 5/25 patients during WPW syndrome. During ventricular tachycardia, the atrial intervals shortened significantly by 21.2 ± 13 ms, whereas during supraventricular tachycardia no change in the atrial rate was observed during ventricular stimulation (1.36 ± 1.16 ms). During the WPW tachycardias, the atrial interval first shortened by 43.6 ± 40.9 ms but then returned to its normal value. These results were statistically significant with a p-value of $p < 0.009$. A graphical representation of the results is shown in Figure 4.

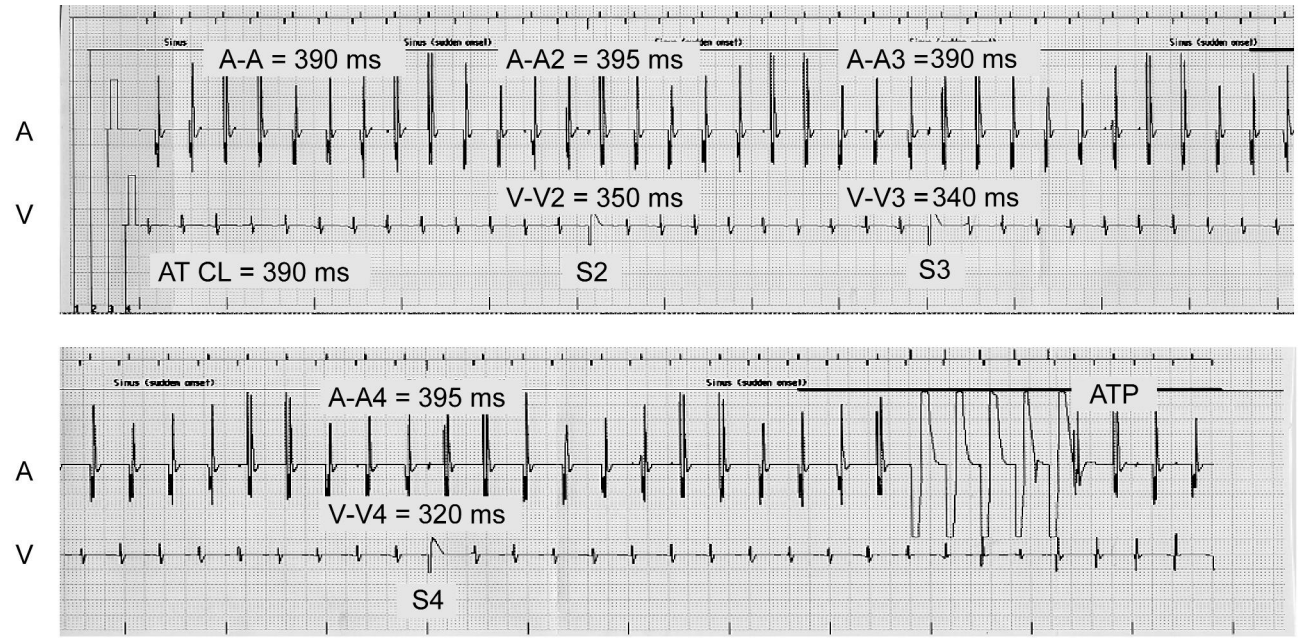

Figure 3. Example for detection of a supraventricular tachycardia by the active discrimination algorithm. Detection success is indicated by the antitachycardic "marker" paces.

Discussion

The new active discrimination algorithm has yielded encouraging results during the acute investigations. The specificity has been increased while no loss of sensitivity for VT detection and no proarrhythmia has been observed. Thus, the use of the algorithm in the two implanted devices may help to further avoid inappropriate shock releases, while at the same time maintaining a high safety standard. A limitation of the study is that only acute data is available and that part of the episodes had been simulated artificially by means of pacing. Yet, it is unlikely that this affects the conclusions drawn with respect to the feasibility and safety of the proposed method. The results justify and demand for a continuation of the investigations and the validation of the algorithm in a prospective follow-up study. Since the prevention of cardiac death by implantable cardioverter defibrillators may be considered as solved today, the main goal of ICD therapy now is to improve the quality of life of the patients. Apart from the implications of the underlying diseases, the main limiting factors are the compromised hemodynamics and the application of defibrillation shocks. With respect to shock releases, the increase of specificity in atrioventricular tachycardia discrimination is one important step. This approach has to be complemented by techniques which prevent the genesis of tachyarrhythmias in the first place, and by reducing the discomfort in those cases where a shock release is still necessary. In terms of fact, it is from a clinical point of view highly desirable to include multisite pacing into the ICD therapy arsenal and to develop techniques for a further reduction of defibrillation energy requirements. Only then will it be appropriate to legitimately use the term "tiered therapy".

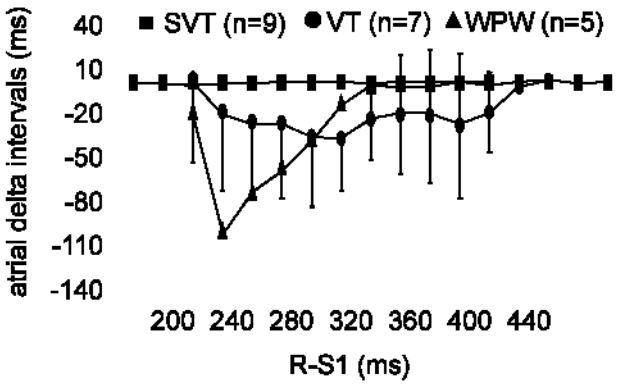

Figure 4. Results with active atrioventricular discrimination during electrophysiologic examination.

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