Antitachycardia Pacing in Implantable Cardioverter Defibrillator Patients - An Overview

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Summary

The development of antitachycardia pacing (ATP) has been a major advance in the electrotherapeutic treatment of tachyarrhythmia and is now a standard option in modern implantable cardioverter-defibrillators (ICD). Nevertheless, many questions about the efficacy of ATP therapy remain to be answered. This paper presents an overview of recent research on ATP. Studies have revealed a circadian variation in ATP efficacy with a low in the morning hours and indicate that postponement of necessary shocks in cases of ATP-failure does not increase mortality. However, no conclusive evidence has been found in the numerous studies that any of the existing ATP modes is more beneficial than the others. For further optimization of ATP therapy, large-scale, controlled, randomized studies are needed.

Key Words

Antitachycardia pacing, implantable cardioverter-defibrillator, ventricular tachycardia, ATP modes

Introduction

Most ventricular tachycardias (VT) seen in clinical practice and in patients receiving an implantable cardioverter-defibrillator (ICD) are based on a reentry mechanism. One of the major characteristics of reentry tachycardias is that they are amenable to initiation and termination by pacing techniques. It is generally accepted that the slower the VT rate, the higher the chances of pacing termination. Vice versa, the faster the VT rate, the lower are the chances of termination and the greater are the chances of accelerating VT.

The introduction of antitachycardia pacing (ATP) to ICD technology is undoubtedly one of the major advances in this field of therapy. ATP has the advantages of rapid and repetitive delivery, minimal or no absent symptoms triggered in the patient, and avoiding unnecessary shock delivery which is very uncomfortable for the patient. Finally, it may prolong battery longevity by preventing battery drain due to high-energy shocks.

All new generations of ICDs incorporate ATP therapy. Each device has a different ATP therapy algorithm. In general, these algorithms are based on the techniques of burst or ramp pacing (figure 1). For example, the Phylax ICD series (BIOTRONIK) has the capability of executing various ATP pacing schemes. To the two main modalities of ATP, burst and ramp pacing, different features can be added, such as the coupling interval scan, start interval scan, programmed extrastimulus (PES), and additional extra pulses (see table 1).

Although ATP has become an accepted modality of therapy in ICD patients and the literature documents numerous studies about this field, proper, large-scale, controlled, randomized studies which examine the effectiveness of ATP therapy are yet to be conducted. Most of the studies investigated small populations, some of them included induced arrhythmias (pre- and post-ICD implantation), whereas others included spontaneous arrhythmias. All large studies are from ICD database companies, and they are retrospective and nonrandomized. Results in terms of ATP efficacy and the ratio of ATP induced rhythm acceleration are depicted in figure 2. However, a large number of questions remain to be answered regarding the need and effectiveness of ATP.

Form	Form	Coupling Intervall Scan	Start Intervall Scan
Burst			
Burst with scanned coupling interval	Burst	yes	
Burst with scanned start interval	Burst		yes
Burst with scanned coupling- and start interval	Burst	yes	yes
Burst + PES	Burst + PES		
Burst + PES	Burst + PES		yes
Burst Add 1	Burst (Add 1)		
Ramp			
Ramp with scanned coupling interval	Ramp	yes	
Ramp with scanned start interval	Ramp		yes
Ramp with scanned coupling- and start interval	Ramp	yes	yes
Ramp Add 1	Ramp (Add 1)		
1 **PES**	1 **PES**		
2 **PES**	2 **PES**		
3 **PES**	3 **PES**		
user-defined ATP	**free**	**yes**	**yes**

Table 1. Antitachycardia pacing (ATP) scheme available in the PHYLAX 06 cardioverter defibrillator (PES = programmed extra-stimulus).

The following provides an overview of the latest research results in the field of ATP therapy and the open questions to be answered by future studies.

General Factors-Circadian Variation

An increased frequency of spontaneous VTs in the morning has been demonstrated in ICD patients [1]. Similarly, a corresponding morning peak in defibrillation energy requirements and in failed first shock frequency has been reported [2]. Recently, Fries et al. [3] demonstrated an inverse circadian variation of ATP therapy success and acceleration in ICD patients. Of 471 ATP-appropriate VT therapies, a typical morning peak (6 a.m. to noon) in VT occurrence was observed. The mean termination rate for ATP therapy for this peak period was 69 % versus 82 % for the rest of the day (p = 0.0125), whereas the mean acceleration rate was 24 % versus 18 % (p = 0.0574). Thus, in the time period with the highest frequency of VT episodes (morning hours), ATP is least successful and the most acceleration occurs.

Effectiveness of Different ATP Algorithm Modes

Although most ICDs offer a wide range of ATP therapies today, little is known about the effectiveness of each type of ATP therapy, leaving the clinical decision to be based on observed individual responses of patients during ICD testing or empirical physician preferences.

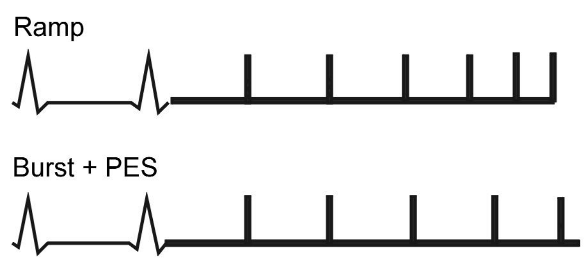

Figure 1. Scheme of an ATP ramp (top). The first stimulus with a programmable coupling interval is followed by a series of stimuli, whose intersection time intervals are shortened stimulus by stimulus. At the bottom: scheme of a burst. The first stimulus with a programmable coupling interval is followed by a series of stimuli delayed by equal time intervals. Here, a further programmed extra-stimulus is added.

Rosenqvist [4][5] reviewed 4 prospective, randomized studies and assessed which algorithm (burst or ramp, see figure 3) was the most efficient in terminating induced VT. Both techniques were equally efficacious in terminating VT with a success rate of 65 % to 90 %. The incidence of acceleration showed a wide variation (3.1 to 21 %), however no difference was found in the incidence of acceleration between the two modes within each study population.

Trappe et al. [6] performed a randomized, prospective study of 3 different ATP modes in 65 patients prior to and after ICD implantation. All 3 ATP modes included 4 stimulation attempts with 4 to 7 adaptive scanning burst pulses. The adaptive burst coupling intervals were 75 % in mode A, 81 % in mode B, and 69 % in mode C. Autodecremental scanning within bursts was 8 ms in all modes, decremental scanning between bursts was 8 ms in modes B and C. Each ATP mode had to be tested 3 times; all 3 ATP modes were randomly applied to each patient. During preoperative testing, 91 of 133 VT episodes (68 %) could be terminated by ATP. Termination was achieved in 68 % with mode A, 68 % with mode B, and 73 % with mode C. During predischarge testing, 251 VTs were induced, and ATP was successful in 147 VTs (59 %). Termination rate was 56 % with mode A, 68 % with mode B, and 50 % with mode C. During the mean follow-up of 12 months, 2301 arrhythmia episodes occurred. ATP was performed in 2097 episodes (91 %) and was successful in 1920 (92 %). Acceleration of VT occurred in 65 arrhythmic episodes (3 %), and unsuccessful ATP was observed in 112 (5 %). It was concluded that ATP in general was highly effective in patients with sustained VT. None of the tested ATP modes, however, proved to be superior to the others.

The purpose of the study by Fries et al. [7] was to determine the termination and acceleration rates for 1 to 6 attempts of ATP delivered by ICD in order to terminate spontaneously occurring VTs. Twenty-four ICD recipients with active ATP programs, including a maximum of 6 ATP sequences, and spontaneously occurring VTs during follow-up were investigated. During a mean follow-up of 42 ± 15 months (range 17 to 63 months), 413 spontaneous VT episodes (17 ± 14; range 1 to 49 per patient) resulting in appropriate ATP delivery by the ICD occurred. Antitachycardia pacing successfully terminated 328 episodes (80 %) with a mean number of 1.6 ± 1.1 pacing sequences. Eighty episodes (19 %) were accelerated by ATP and 5 (1 %) were unresponsive to ATP. The ATP success decreased until the third ATP sequence (59 % to 31 % to 24 %), but increased again in the fourth to sixth attempt (46 % to 46 % to 29 %). The acceleration rate increased from sequence one to sequence three (8 % to 13 % to 28 %), but decreased significantly in further ATP attempts (19 %, 0 %, 0 %). The mean time delays until redetection or termination after 4, 5, and 6 ATP attempts were 22 ± 5 seconds, 37 ± 2 seconds, and 41 ± 9 seconds, respectively. Nine patients (37 %) used ≥ 3 ATP attempts during follow-up and all patients benefited therapeutically. Five out of 13 VTs (38 %) treated with ≥ 4 attempts could be ultimately terminated by ATP.

The results of this study demonstrated that the first ATP sequence is the most effective and that ≥ 4 ATP attempts may be useful in a minority of patients. The risk of VT acceleration seems to be low by the fourth to sixth ATP sequence. However, because extra time elapses with increased sequences, a high number of ATP attempts should only be programmed in patients with stable VTs that are tolerated hemodynamically well.

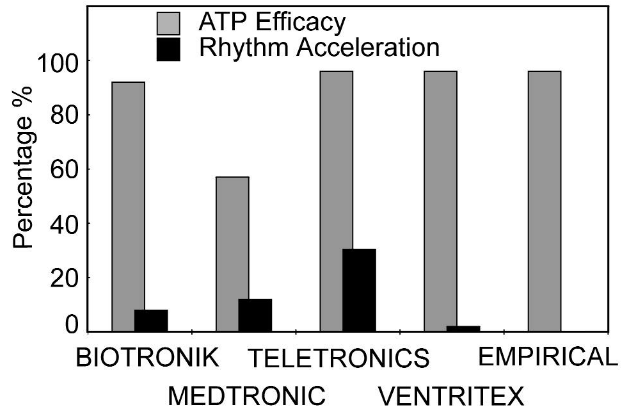

Figure 2. Comparison of reported ATP efficacy and the ratio of ATP induced rhythm acceleration. The results are with respect to different ICD manufacturers and an empirical ATP setting (see text).

Data Derived from ICD Follow-up Studies

1. BIOTRONIK - Phylax 06 follow-up study [8]:
Information regarding the Phylax 06 ICD is available in the form of a follow-up database assembled with data from clinics in Halle and Dessau [8]. A recently introduced patient data management system was

employed during the follow-up procedure which allows automatic transmission of the entire ICD Holter to the database. After implantation of the Phylax, the Holter data of 31 patients were recorded during an average follow-up period of 6.7 ± 3.6 months. During this period, 422 VT episodes were initially detected. Moreover, 462 VT episodes were classified as redetected. Three hundred eighty-seven (92 %) of the initially detected episodes were successfully terminated by ATP delivery, while 32 (8 %) of them were accelerated and 9 (2 %) were decelerated by this type of therapy. In 34 cases, only a shock led to termination of the episode. On two occasions, shock delivery was interrupted. Including the redetected episodes, a total of 846 ATP attempts was delivered, yielding an average of 2.2 ATP attempts necessary for terminating an episode. In total, 107 VT episodes were treated by a shock. Thirty-four of them led to termination, but 51 shocks were ineffective. Furthermore, 2 shocks accelerated the particular episode, while 18 instances of defibrillation resulted in deceleration.

2. Medtronic multicenter PCD investigation [9]:
This multicenter study reported the outcome of VT therapy (conversion or acceleration) and the relationship between therapy success and the initial tachycardia cycle length, as well as other clinical variables, using an implantable device with the capability of autodecremental or burst pacing, cardioversion, and defibrillation. The device was implanted in 444 patients (mean age 58 ± 15 years); 1240 episodes of VT were induced with noninvasive programming and entered into a multicenter database.
In attempting conversion by pacing or cardioversion (with 0.2 to 5 J), only the first therapy sequence was assessed. Autodecremental pacing was used to treat 700 induced episodes of VT during application of pacing therapies (57 % converted and 12 % accelerated), burst pacing to treat 357 episodes (49 % converted and 11 % accelerated), and cardioversion to treat 183 episodes (82 % converted and 4 % accelerated). Cardioversion was the most effective treatment and had the lowest acceleration rate. Shorter VT cycle lengths were more likely to accelerate with burst pacing, whereas for longer VT cycle lengths, conversion was more favorable with both burst and autodecremental pacing. Patients with higher ejection fractions best responded to conversion with autodecremental and burst pacing. Cardioversion, higher ejection fractions, absence of unrepaired aneurysms, longer VT cycle lengths, coronary artery disease, and autodecremental pacing predicted conversion. Lower ejection fractions and a VT cycle length shorter than 300 ms predicted tachycardia acceleration.

3. Telectronics multicenter Guardian ATP 4210 study [10]:
In this study, stored information from data logs was retrieved from 401 implanted ICDs in 393 patients over an average of 303 days of follow-up. A total of 91443 detections were recorded in 299 patients. One hundred six patients (26 %) had detections due to supraventricular tachycardias, electrical noise, or other causes, resulting in inappropriate therapy delivery to 92 patients (23 %). Two hundred eighty-one patients recorded 66276 episodes of VT or ventricular fibrillation (VF). Of these, 74.4 % episodes terminated spontaneously without any delivered therapy, 22.1 % terminated after ATP, and 1.7 % terminated after shock therapy. ATP was activated without formal testing in 47 % of all patients receiving this therapy and was successful in 96 % of all episodes receiving this therapy. Tachycardia acceleration requiring shock therapy occurred in 1.3 % of all episodes and in 30.5 % of patients receiving ATP. Thirty-four patients (8.7 %) died during follow-up. Mortality was associated with patient age, heart failure function class at implantation, and frequency of shocks received during follow-up (all $p \leq 0.05$).

4. Ventritrex - Cadence V - 100 database [11]:
In this database, information was available from 1719 cases, and 933 patients were programmed with ATP at sometime during their follow-up. The only selection criterion applied was that patients needed to have sustained one or more diagnosed episode of spontaneous VT while their device was activated to deliver ATP, identifying 434 cases total in the database.
During a mean follow-up of 758 ± 333 days, the patients experienced 51 ± 119 episodes on average, totaling 22339 episodes. Successful termination, failure, and acceleration occurred in 21003 (94 %), 1023 (4.6 %), and 313 (1.4 %) of the treated episodes, respectively. The 1023 episodes not terminated by pacing responded to subsequent cardioversion or high-voltage defibrillation, the latter therapy also being successful in the 313 episodes complicated by acceleration. Mean VT cycle lengths for episodes responding with termination, failure, and acceleration averaged 395 ± 65,

390 ± 64, and 347 ± 54 ms, respectively. VT cycle length associated with acceleration did not differ between autodecremental and burst pacing. Success rates of ATP for the two most commonly programmed ranges of stimuli per burst (6 to 10 and 11 to 15) were similar (94 % and 96 %). However, in patients (n = 17) with rare programming of a greater number of stimuli (16 to 20 per burst), success occurred at a lower percentage (n = 13 or 77 %). Pacing success rates for varying burst numbers (range 3 to 15 bursts) lay within the narrow range of 94 % to 97 %. Failure rates with <6 bursts were slightly higher than with 7 to 15 bursts (5 % to 7 % vs 2 % to 4 %; $p < 0.001$). Acceleration was very low (<2 %) and irrespective of the number of bursts delivered. With autodecremental pacing (n = 7611 episodes), success, failure, and acceleration rates were 94 %, 5 %, and 1 % to 2 %, respectively. These values were identical to those without autodecremental pacing (n = 14728 episodes). Termination, failure, and acceleration rates with (n = 19755 episodes) or without (n = 2584 episodes) scanning yielded the same values of 94 %, 5 %, and 1 % to 2 %. These values remained unchanged when autodecremental pacing and scanning were used in all possible combinations. The adaptive percentage of the coupling interval was evaluated by examining success rates of pacing for patients programmed in each of the 5 % windows for adaptive percentages ranging from 50 % to 100 %. In only 1 % of the cases was the percentage programmed at < 70 %. Over half of the cases were programmed within the 81 % to 85 % range. The success rate for the 81 % to 85 % range was significantly lower than that for the 71 % to 75 % range (94 % versus 99 %).

5. Empirical ATP Therapy

Siebels et al. [12] programmed "empirical" ATP in 8 patients with clinically documented VT who were noninducible at predischarge testing. All patients were programmed with a "standard" program that had been effective in 10 patients in whom VT was inducible. The program consisted of ramp therapy with an initial sequence of 3 pulses, 81 % coupling interval, 10 ms interval decrement, and 5 sequences. This algorithm had terminated 71 % of the induced tachycardia (n = 48) and caused acceleration in 19 %.

During follow-up, 661 episodes of tachycardia were reported, of which 95 % were successfully terminated by pacing. Acceleration was seen only in 0.2 %. Five of the 8 patients with "empirical" therapy sustained episodes of tachycardia during follow-up. In 4 patients, tachycardias were terminated by pacing. Wood et al. [10] reported a success rate of 96 % for ATP in 150 patients receiving this therapy during follow-up, although only half of them had their ATP algorithm formally tested at discharge. Furthermore, there was no increased risk of acceleration among those who had empirical ATP programming. Schaumann et al. [13] programmed an empirical ATP program of 81 % ramp pacing with 3 sequences comprising 8 to 10 stimuli in 2 groups of VT patients: one with inducible VT that was terminated by ATP (n = 27) and one with noninducible VTs (n = 65). During 12 months of follow-up, almost 1500 spontaneous VT episodes occurred. There was no difference in the success rate (87.5 % vs 87.2 %) between the 2 groups.

ATP and Mortality

A final point of consideration is whether the introduction of ATP therapies, which in certain cases may postpone effective therapy (due to failed ATP attempts), may negatively balance the net effect of ICD therapy on mortality. It is conceivable that failing ATP therapies, which lengthen arrhythmia duration and possibly ischemic injury to the myocardium, may contribute to increased mortality. The only information regarding this issue is the study by Ellenbogen et al. [14] which compared three generations of CPI ICDs. The total mortality was lower for patients receiving new generation ICDs with ATP capabilities than those receiving ICDs with only shock capabilities. The probability of surviving sudden cardiac death remained similar among all three groups.

Conclusion

Despite the extant need for large controlled studies, ATP appears to be an effective modality of treatment for ICD patients affected by VTs. As indicated by Rosenqvist [4,5], ATP is highly efficient for VT termination with a success rate of about 80 % to 90 %. The ATP algorithm used is of less importance, with either method (burst or ramp) being equally effective. It seems that ATP may be used with a high degree of success in VT patients, despite the lack of pre-discharge testing (empirical ATP).

ATP success can be influenced by many factors, such as the time of day when the tachycardic episode occurs, the cycle length, the ejection fraction, and existing cardiac diseases. The high success rates with ATP therapy and the suggestion that it lowers total mortality should inspire efforts for its further optimization. To this end, large-scale, controlled randomized studies will have to be conducted to find optimal ATP algorithms and thus to extend the benefits of tachyarrhythmic therapy.

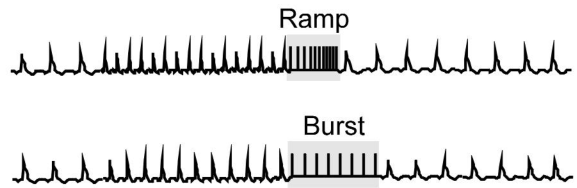

Figure 3. IEGM examples, showing an VT episode which is detected by the ICD and successfully treated with a burst or ramp ATP, as demonstrated by the following sinus rhythm.

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