Intrinsic antitachycardia pacing for patients with multiple ventricular tachycardias

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Introduction

Antitachycardia pacing (ATP) offers a safe and painless termination of ventricular tachycardia (VT) in patients with implantable cardioverter-defibrillators (ICDs).[1] However, it is accompanied with some limitations: ATP success rates are as low as 50% for fast VT, with a cycle length (CL) of <300 ms, and VT acceleration may occur in up to 10% of ATP therapies.[2,3] Intrinsic antitachycardia pacing (iATP) provides an automatic and tailored ATP for each VT in real time.[4] An iATP algorithm delivers the equivalent of a train of burst pulses (S1) followed by 1 (S2) or 2 (S2-S3) ramp-plus pulses. The uniqueness of the iATP algorithm derives from the fact that it adjusts the number of S1 pulses and the coupling interval (CI) of S2 according to individual VTs. When the initial ATP sequence fails to terminate VT, iATP makes 2 modifications. First, iATP calculates the number of S1 pulses required to entrain the VT circuit using postpacing interval (PPI). Second, the device decrements the S2 pulse interval until it terminates the VT.

Herein, we describe 2 cases in which iATP successfully terminated multiple VTs with different CLs and morphologies.

KEY TEACHING POINTS

- While antitachycardia pacing (ATP) is employed to terminate ventricular tachycardias (VTs), it is less effective against fast VTs and has the potential risk of VT acceleration.
- Intrinsic antitachycardia pacing (iATP) is an automated ATP algorithm that allows individualized therapy. The algorithm employs 2 unique features: burst pulses (S1) that analyze the postpacing interval following a failed ATP sequence, and ventricular extrastimulation (S2, S3).
- Although there are reports of iATP terminating VT in clinical settings, there are still no reports of its effectiveness in multiple VTs with different VT circuits.
- We present 2 cases where iATP successfully terminated multiple VTs with different cycle lengths and morphologies. This novel ATP algorithm has the potential to terminate multiple VTs with a remarkably high likelihood of success.

Case report

A written informed consent for the publication of their details was obtained from the patients.

Case 1

A 72-year-old male patient with dilated cardiomyopathy experienced recurrent VTs, even with amiodarone and beta-blocker therapy, and underwent catheter ablation for VTs (class IIa indication).[5]

Even after ablation, the VT was not eliminated. Subsequently, he received an ICD (Cobalt XT DR MRI; Medtronic, Minneapolis, MN) for VT.

Two days after ICD implantation, VT with a CL of 460 ms (VT1) was initiated (Figures 1 and 2). The first sequence of iATP included 6 S1 pulses with a CL of 410 ms (88% of the VT CL), followed by an S2 pulse with a CI of 320 ms, which failed to terminate the VT. After a PPI of 680 ms, the same VT was detected. A second ATP sequence was delivered with 6 S1 pulses having a CL of 410 ms, followed by an S2 pulse with a CI of 290 ms, leading to VT termination.

VT (VT2) occurred 1 year later, with a longer CL of 540 ms. The ventricular electrogram was different from that previously observed in VT1. The first sequence of iATP consisted

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of 5 S1 pulses with a CL of 470 ms, followed by an S2 pulse with a CI of 340 ms, which failed to terminate the VT. Based on the analysis of the PPI of 830 ms, the second sequence of ATP was delivered with 6 S1 pulses, with a CL of 470 ms, followed by an S2 pulse with a CI of 310 ms, and VT was terminated. The patient did not undergo conventional ATP/shock therapy because all VTs were terminated by iATP during the follow-ups that lasted for 18 months.

Case 2

A 64-year-old male patient with dilated cardiomyopathy underwent cardiac resynchronization therapy defibrillation (CRT-D) (Cobalt XT HF; Medtronic) implantation following an episode of syncope due to VT. A month after discharge, despite amiodarone and beta-blocker therapy, VT with a CL of 380 ms (VT1) recurred, and the first sequence of iATP was initiated (Figure 3). The sequence included 6 S1 pulses with a CL of 330 ms (88% of the VT CL), followed by an S2 pulse with a CI of 310 ms with successful VT termination. However, another VT (VT2, CL 390 ms) occurred with a different ventricular electrogram the next day. iATP was delivered with 6 S1 pulses with a CL of 340 ms, followed by an S2 pulse with a CI of 320 ms, leading to VT2 termination. VT (VT3, CL 420 ms) recurred a month later with a different ventricular electrogram from VT1 and VT2. Again iATP was delivered, with 6 S1 pulses having a CL of 370 ms, followed by an S2 pulse with a CI of 340 ms, resulting in VT termination. Since then, VT has reoccurred thrice (VT1 twice and VT3 once), and was terminated using iATP every time. In summary, 3 types of VTs were recorded a total of 6 times during the first 6 months following device implantation. All 6 incidences of VT were successfully terminated by iATP, without undergoing subsequent device therapy (conventional ATP/shock).

Discussion

Although there have been case reports of iATP showing its efficacy in clinical settings,[6,7] there are still no reports demonstrating the effectiveness of iATP against multiple incidences of VT in the same patient. iATP is a novel algorithm that can deliver arrhythmia-specific therapy. To terminate VT, the device calculates the number of S1 pulses from the mean VT CL and the propagation time it takes for a paced pulse to reach the VT circuit. In the first sequence, the device estimates the S2 pulse interval from the V-V rate history leading up to episode detection. If an S1 pulse penetrates the VT circuit, a successful S2 pulse then renders the VT circuit refractory and terminates the VT. If the first sequence does not terminate the VT, the device decrements the S2 pulse interval for efficacy with each subsequent S1-S2 sequence until it terminates the VT.

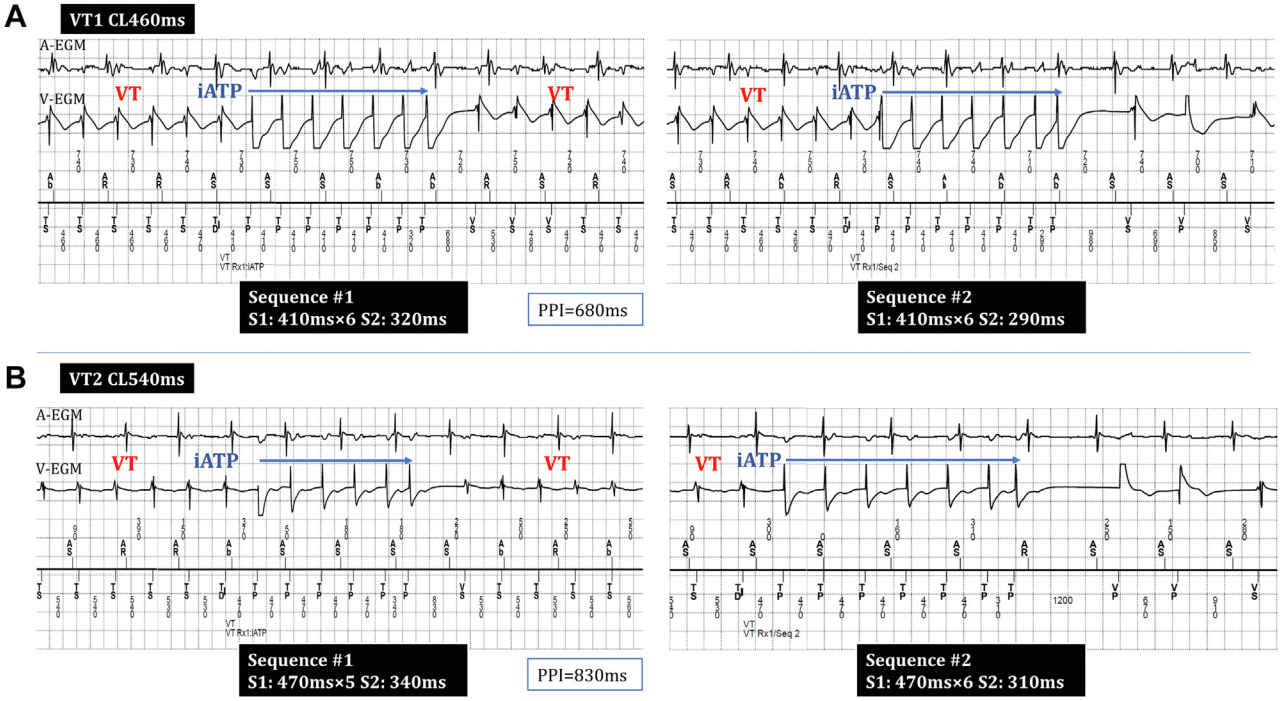

Figure 1 Case 1: Intracardiac electrogram (EGM) of ventricular tachycardia (VT). **A:** VT1. **B:** VT2. VT1 and VT2 had different cycle lengths (CL) (VT1, 460 ms; VT2, 540 ms) and ventricular EGM (V-EGM). Propagation time, calculated as postpacing interval (PPI) minus VT CL divided by 2, differed between VT1 and VT2 (110 ms and 145 ms, respectively). Intrinsic antitachycardia pacing (iATP) failed to terminate VTs in the first sequence. However, based on PPI, the second sequence varied the series of pulses of the ATP and terminated both VTs. It should be noted that in VT2, iATP automatically increased the number of S1 pulses (from 5 to 6) using PPI analysis. A-EGM = atrial EGM; PT = propagation time.

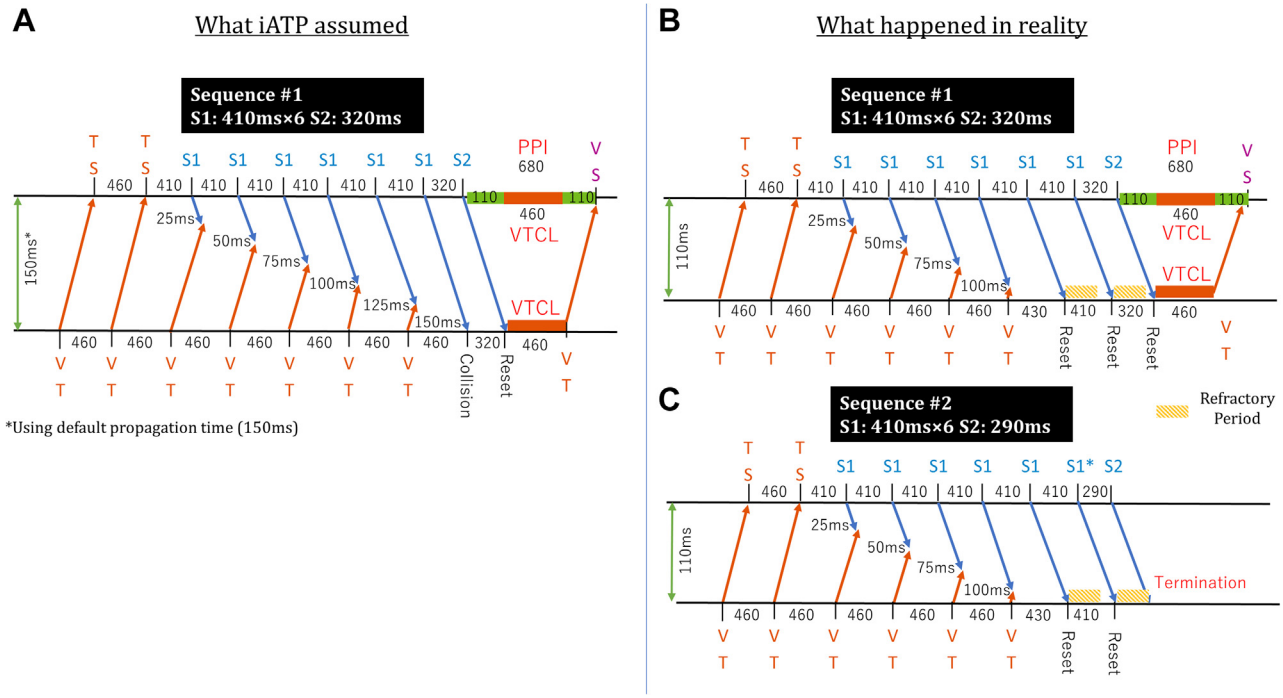

Figure 2 A detailed analysis of antitachycardia pacing (ATP) pulses against ventricular tachycardia 1 (VT1) (case 1) using a laddergram. **A:** How intrinsic ATP (iATP) most likely approached VT1: In this case, the collision site between the S1 pulse and VT excitation approached the VT circuit by 25 ms (VT cycle length [VTCL] minus S1 divided by 2) for each S1 pulse. Considering the default assumption of a propagation time of 150 ms, the required number of S1 pulses should be 6. Using this calculation, the first sequence of iATP consisted of 6 S1 pulses and S2 pulses with an automated coupling interval (CI) of 320 ms. Although VT was sustained, the postpacing interval (PPI) was measured to be 680 ms, and the real propagation time was 110 ms. **B:** What happened during the first sequence of iATP in VT1: The number of S1 pulses required to reach the VT circuit was calculated as 5 (110 ms divided by 25 ms, rounded up), and the reset by the S1 pulse should have attained 5 pulses. Because S2 with a CI of 320 ms was not short enough to reach the nonexcitable refractory region, VT was still sustained. **C:** How the second sequence of iATP terminated the VT1: The second sequence of iATP included 6 S1 pulses and S2 pulses with a decremented CI of 290 ms, which reached the nonexcitable refractory region, thereby terminating VT. It should be noted that the number of pulses required for S1 was calculated to be "5," but iATP delivered 6 pulses. This is because iATP always increases the number of pulses by 1 or 2 to ensure that S1 resets the VT.

In case 1, the initial iATP sequence failed to terminate the VT.

A detailed analysis of VT1 can provide a better understanding of the advantages of the iATP unique algorithm (Figure 2). The PPI observed was 680 ms, and ATP was able to reset the VT without termination. The propagation time from the pacing site to the VT circuit, calculated based on the PPI, was 110 ms, and the number of S1 pulses required to entrain the VT circuit was 5. iATP is capable of automatically adding 1 or 2 S1 stimuli, in addition to the required number of S1 pulses, to ensure the entraining of the VT circuit. Therefore, the ATP delivered an S1 burst of 6 pulses. Subsequently, S2 was shortened from 320 ms to 290 ms in the second sequence, which successfully terminated the VT. The same was observed in ATPs against VT2. It is important to note that the CL of VT2 was significantly longer than that of VT1, 540 ms and 470 ms, respectively. More importantly, the propagation time also differed between the 2 VTs (VT1: 110 ms vs VT2: 145 ms), and the distance from the pacing lead to each VT circuit was also different. These findings led us to conclude that VT2 was entirely different from VT1. Even against VTs presenting with different CLs and propagation times, the second sequence of iATP terminated VT2. One of the reasons ATP fails to successfully terminate VT is that, frequently, the S1 pulse does not reach the VT circuit.[1] The fact that iATP can vary the number of S1 pulses according to propagation time is a great advantage in ensuring that the pulse penetrates the VT circuit when used against different VTs.

In case 2, 3 different VTs were recorded. Although the CLs were similar, the ventricular electrograms were significantly different between the 3 VTs. Furthermore, the electrogram morphologies recorded in the wavelet were also significantly different between the 3 VTs,[8] amounting to the evidence that there were 3 different types of VTs (Figure 3). iATP automatically delivered a different S1 burst pacing and extrastimulation during S2, according to each VT, and terminated all VTs in the first sequence. Given that the S1 pulse interval was 88% of the VT CL, which is equal to the conventional setting of ATP recommended in the focus-updated guidelines,[9] it is plausible that the unique S2 stimulation by iATP results in a high VT termination rate. iATP possesses a unique mechanism that allows the S2 pulse to render the VT circuit refractory, and thus terminate the VT.

Although setting iATP as an initial therapy option may result in hemodynamic collapse owing to the increased time to initiate ICD shock, previous studies have shown that it does not increase the incidence of syncope.[10] In addition, in the present case, it should be noted that the patient was

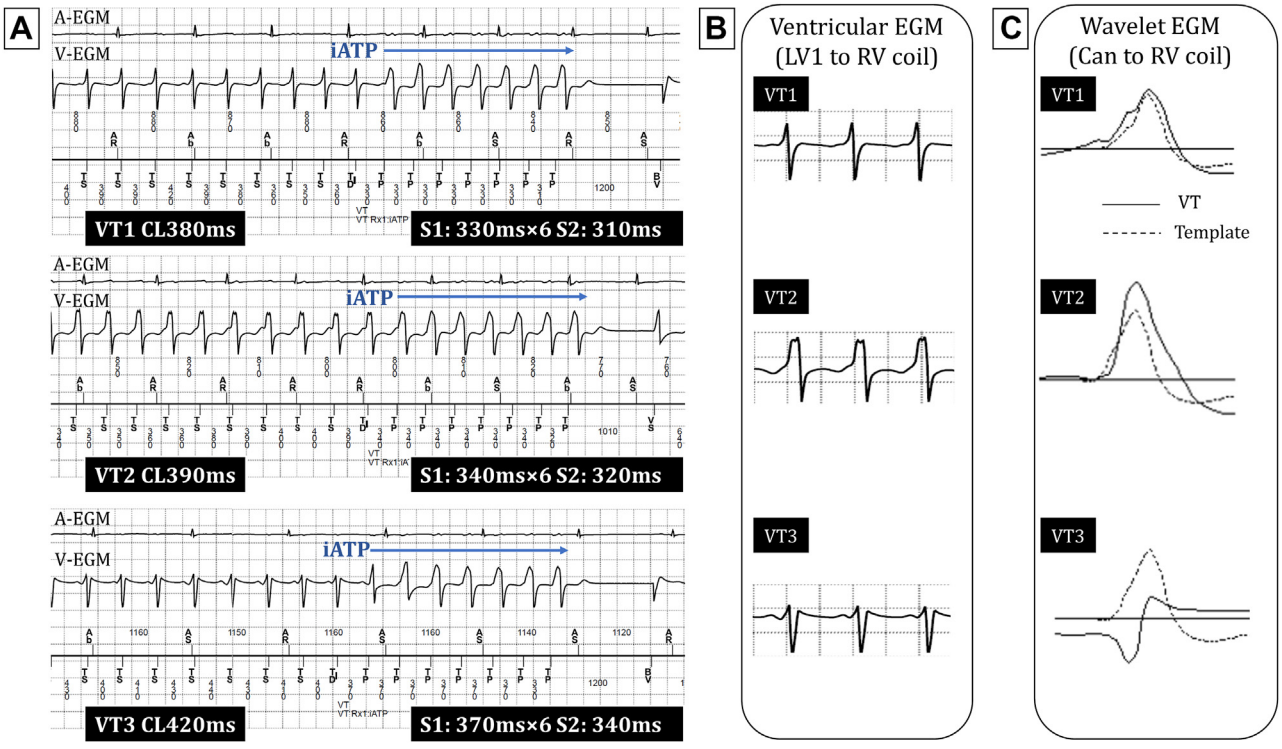

Figure 3 Case 2: Intracardiac electrogram (EGM) and wavelet. **A:** Intracardiac EGM. The first sequence of intrinsic antitachycardia pacing (iATP) involved 6 S1 pulses (88% of the ventricular tachycardia [VT] cycle length [CL]) followed by an S2 with coupling interval (CI) of 310 ms, 320 ms, and 340 ms that terminated each VT, respectively. **B:** Ventricular EGM. **C:** Wavelet EGM. Both ventricular EGM and wavelet EGM were different for all 3 VTs. A-EGM = atrial EGM; PPI = postpacing interval; PT = propagation time; V-EGM = ventricular EGM.

asymptomatic during VTs because all VTs were promptly terminated by iATP and hemodynamic collapse was spared.

The efficacy of iATP for fast VT (CL <300 ms) cannot be addressed from these 2 cases. Further investigation on VT termination rate by iATP according to VT CL is needed. Finally, large clinical trials with a crossover design between ATP and iATP are expected to prove the advantages of iATP.

Conclusion

This is the first case report highlighting how iATP can terminate multiple VTs in a clinical setting. The iATP algorithm has the potential to provide individualized therapy and terminate multiple VTs with a high likelihood of success.

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