First experience of temperature-controlled bipolar radiofrequency ablation of ventricular tachycardia originating from the anterior left ventricle using a diamond-embedded-tip catheter

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Introduction

Radiofrequency (RF) catheter ablation is an effective option for ventricular tachycardia (VT) in many patients, but its efficacy is limited when the origin of the VT is intramural. Bipolar ablation is an approach for patients who have failed conventional unipolar ablation. The efficacy and safety of bipolar ablation is gradually being recognized, although devices specifically for bipolar ablation are not widely available and often have to be custom made.

We present the first case of intramural origin in which temperature-controlled bipolar ablation using a diamond-tipped catheter with 6 thermocouples was performed safely and effectively.

KEY TEACHING POINTS

- To our knowledge, this is the first case report of bipolar ablation in a temperature-controlled mode using a DiamondTemp Ablation (DTA) system (Medtronic, Inc, Minneapolis, MN).
- Bipolar ablation can be safely performed using DTA as an active catheter in a temperature-controlled mode.
- Because the maximum tip temperature and impedance drop showed a moderate correlation, the DTA tip temperature may also be a safety index for bipolar ablation.

Case report

A 73-year-old woman with diagnosis of nonischemic idiopathic cardiomyopathy was brought to our hospital by ambulance with sustained VT refractory to antiarrhythmic drugs. Cardiac magnetic resonance imaging was not performed because of renal function impairment. After implantable cardioverter-defibrillator (ICD) implantation, VT relapsed repeatedly, and multiple antitachycardia pacing (ATP) and ICD shocks were provided despite the administration of amiodarone, sotalol, and bisoprolol. Catheter ablation of the endocardium was performed; however, no low-voltage area or delayed potential was observed in the left ventricle. VT was easily induced by pacing with a right bundle branch block–inferior axis configuration, consistent with an anterolateral left ventricle (LV) exit, and was diagnosed as reentry on findings of constant and progressive fusion. Hemodynamics were maintained during VT, activation mapping was performed, and the earliest activation area during VT was as early as the QRS onset. Sequential unipolar ablation at the earliest site of the endocardium of the LV was performed but had no effect on VT. After the epicardial approach, epicardial voltage mapping was performed; however, the voltage on the epicardial side was also normal, and no delayed potential was detected. The earliest excitable site of the epicardium during VT preceded QRS onset by approximately 10 ms. After coronary angiogram, sequential unipolar ablation and simultaneous unipolar ablation between the epicardium and endocardium were attempted with a ThermoCool STSF and CARTO system (Biosense Webster, Diamond Bar, CA) and a FlexAbility catheter (Abbott, Inc, Chicago, IL) but had no effect on the VT. After unsuccessful ablation of the endocardium and epicardium, VT repeatedly recurred, despite intensive drug therapy. Owing to frequent ATP and ICD shocks and previous ablation

KEYWORDS Bipolar catheter ablation; Ventricular tachycardia; Intramural origin; Temperature-controlled mode; Diamond-embedded-tip catheter
(Heart Rhythm Case Reports 2023;9:529–533)

Funding Sources: This research did not receive any specific grants from funding agencies in the public, commercial, or not-for-profit sectors. Disclosures: None. **Address reprint requests and correspondence:** Dr Osamu Inaba, Department of Cardiology, Japanese Red Cross Saitama Hospital, 1-5, Shin-Toshin, Chuou-ku, Saitama-shi, Saitama, Japan. E-mail address: oinbcvm@tmd.ac.jp.

https://doi.org/10.1016/j.hrcr.2023.05.003

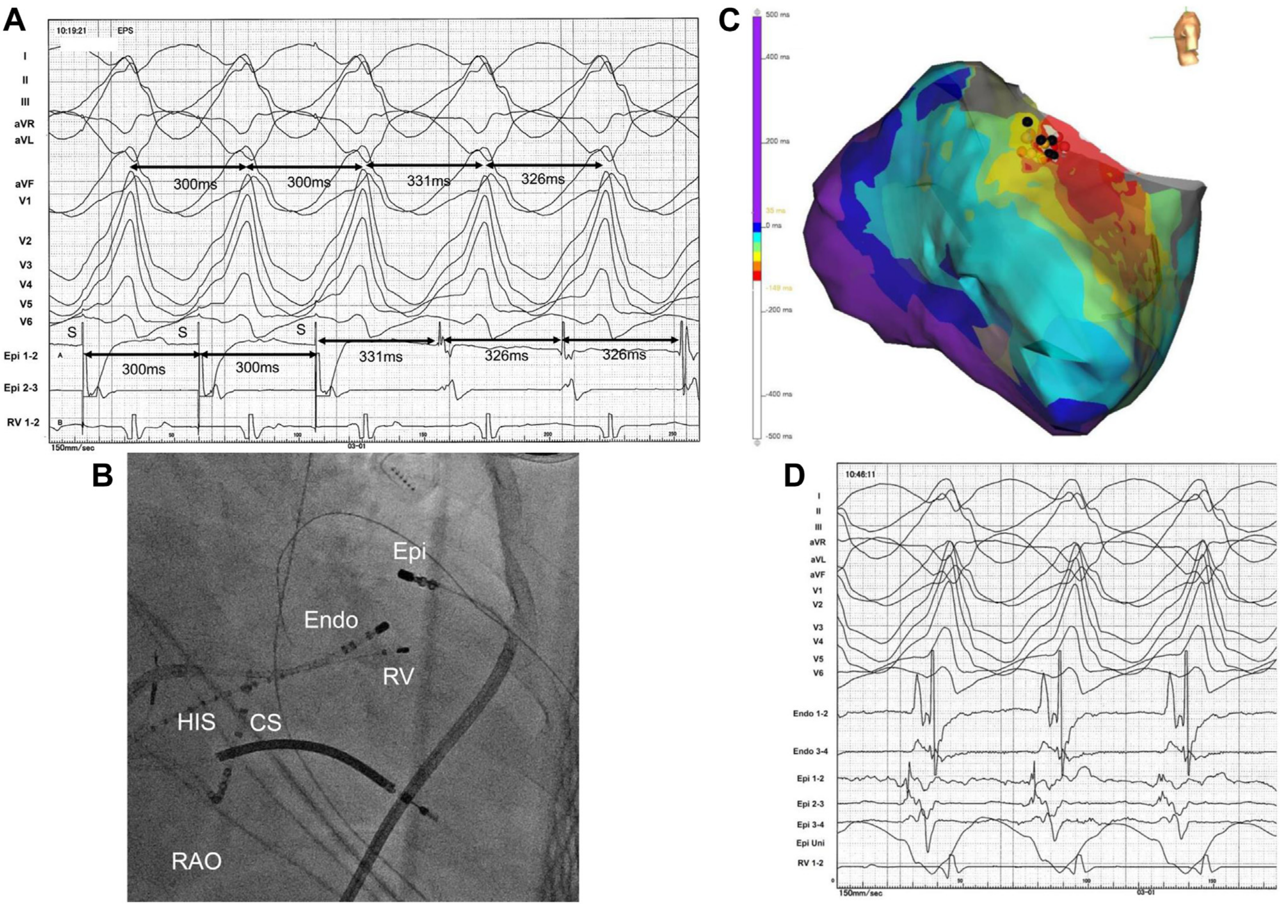

Figure 1 An intracardiac electrocardiogram, fluoroscopy, and 3-dimensional electroanatomical mapping findings of successful ablation site. **A:** Entrainment pacing at the earliest excitation site on the epicardium showed concealed fusion, and the postpacing interval was equal to the cycle length of the ventricular tachycardia (VT), but stimulation-QRS duration was less than 10% of the cycle length of the VT. **B:** A fluoroscopic image of successful ablation site. **C:** A 3-dimensional electroanatomical map of left ventricle. **D:** A local electrocardiogram of successful ablation site during VT. CS = coronary sinus; ECG = electrocardiogram; Endo = endocardium; Epi = epicardium; HIS = His bundle; RAO = right anterior oblique; RV = right ventricle.

with conventional methods, the decision to perform bipolar ablation was made after local ethics committee approval.

Activation mapping of the epicardium with a 20-electrode catheter was performed using the EnSite precision system, which showed that the basal anterolateral region was the earliest excitable region. Entrainment at this site showed concealed fusion and postpacing interval was equal to the cycle length of the VT; however, stimulation–QRS duration was less than 10% of the cycle length of the VT (Figure 1A). Unipolar ablation from epicardium was attempted again multiple times but was ineffective for VT. After confirmation of the location of the coronary artery, bipolar RF energy was delivered to this region between a DiamondTemp Ablation (DTA) system (Medtronic, Inc, Minneapolis, MN), an active catheter situated at the anterolateral epicardium of the LV that activated the earliest, and a TactiCath Quartz catheter (Abbott, Inc, Chicago, IL) as a return catheter placed on the opposing endocardial LV surface via the transatrial septum that activated the earliest of the endocardium during VT, serving as the ground electrode with an interelectrode distance of 20 mm (Figure 1B–1D). A TactiCath Quartz catheter was connected to a T-type cable (Abbott, Inc, Chicago, IL) via TACTISYS QUARTZ (Abbott, Inc, Chicago, IL) for monitoring contact force. The T-cable included an RF generator connector, which was left unplugged in this scenario, as well as pins through which mapping electrodes from the ablation catheter could be directly pinned into a recording system.

Three of 4 proximal pins were connected to the recording system, allowing visualization of the electrogram from the grounding catheter, and allowing for it to be simultaneously visualized along with the active ablation catheter on the EnSite system. The distal pin was connected to the RF generator of the DTA ground-pad plug using a so-called alligator clip cable (Figure 2A). The energy was delivered at 25 W and increased to a maximum of 45 W for up to 90 seconds and was discontinued if the generator impedance dropped by 40 ohms or more or the diamond tip temperature rose by 55°C. The return electrode was irrigated at a cooling rate of 30 mL/min saline regardless of power and contact force during application was controlled within 20 g, and RF delivery was stopped when contact force exceeded 20 g. Temperature of the tip of the return catheter was not able to be monitored.

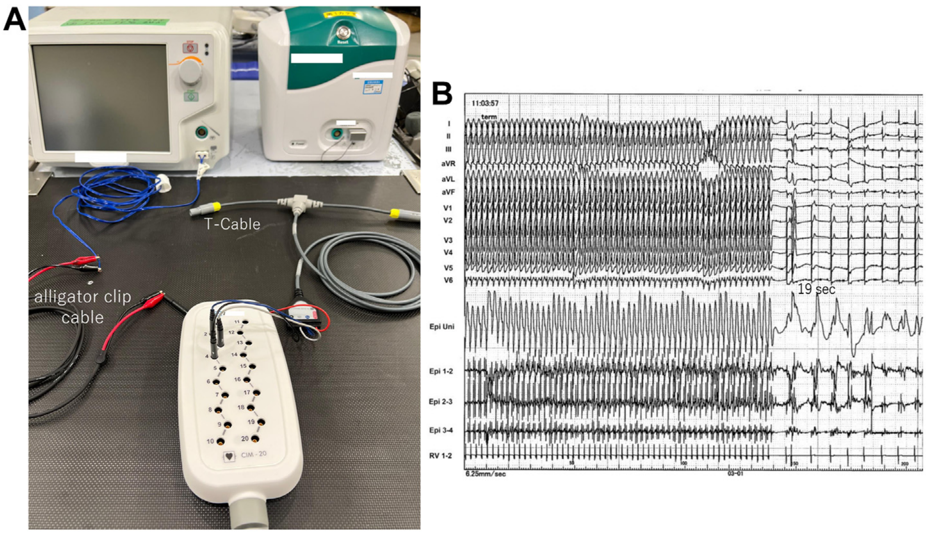

Figure 2 A bipolar ablation circuit of the present case and an electrocardiogram of ventricular tachycardia (VT) termination. **A:** T-cable and associated connection included in bipolar ablation circuit. **B:** VT termination during the third radiofrequency current application.

At the third RF application, VT was terminated 19 seconds after the beginning of the application (Figure 2B). Additional RF currents were delivered because nonsustained VT could be induced by ventricular programmed stimulation, and after 22 additional RF current applications were delivered under the same conditions of targeted temperature of 55°C, VT could not be induced even by 3 extra programmed stimulations from the right ventricle. During a 7-month follow-up period, there were no ICD shocks or ATP.

Discussion

Intramural origin, inaccessible to conventional endocardial or epicardial approaches, is a common finding in patients with nonischemic cardiomyopathy who are undergoing catheter ablation for VT. To suppress VT of such origin, it is necessary to form a deep transmural lesion. However, it might be challenging to identify intramural substrates accurately from either the ventricle or epicardium, and standard unipolar ablation might fail to create lesions of sufficient depth to abolish the substrate. Bipolar ablation has been reported to be beneficial for ablating intramural substrates of VT as an alternative to conventional or simultaneous unipolar ablation.[1] The efficacy, safety, and complication rate of bipolar ablation are gradually being recognized.[2,3] Furthermore, the safety of bipolar ablation to areas such as the vicinity of the conduction system has been reported. Futyma and colleagues[4] also reported that in 8 VT/premature ventricular beat cases from the parahisian area, VT/premature ventricular beat was successfully treated by bipolar ablation in 6 patients. In these patients, transient atrioventricular conduction disturbances, possibly due to mechanical compression, occurred in 2 patients, and steam popping without consequences occurred in 2 patients. They described that RF current traveling between 2 tips of electrodes is more condensed at the area of interest compared with standard RF delivery between ablation electrode and dispersive patch localized at the patient's back, and delivering bipolar RF current outside the His bundle (below or above the His bundle) can possibly increase safety.[4]

Based on these reports, bipolar ablation can be a promising option for applying RF current to intramural substrates of VT; however, its safety index has not been well established. As data on tissue temperature during bipolar RF ablation are limited, careful monitoring of the return catheter temperature as a surrogate is recommended to prevent core overheating and steam popping.[3,5] During the ablation procedure in the presented case, we used a 3.5-mm-tip open irrigated catheter, unsuitable for temperature monitoring, as a return catheter to prevent char formation owing to tip overheating by obtaining effective tip cooling using a saline irrigation, as previously reported.[6]

In the present case, cardiac magnetic resonance imaging was not possible owing to renal dysfunction, and the intramural substrate was determined based on cardiac electrophysiology findings. After multiple failures of the endocardium and epicardium ablation, bipolar ablation was performed. However, because the estimated intramural substrate was in the LV free wall, the risk of perforation was thought to be high when steam popping due to bipolar ablation occurred. Therefore, we decided to use a temperature-controlled ablation mode with DTA for the bipolar ablation.

DTA is a recently developed ablation system based on a diamond-embedded composite tip, temperature sensing, and a saline-irrigated RF ablation catheter with 6 insulated thermocouples on the ablation tip surface, which can directly measure the tissue surface temperature. This novel split-tip electrode provides real-time high-resolution electrograms and impedance recordings. Six external thermocouples on the split tip accurately measure the tip tissue temperatures. The DTA system provides a temperature-controlled ablation mode with rapid diffusion of heat owing to the diamond-

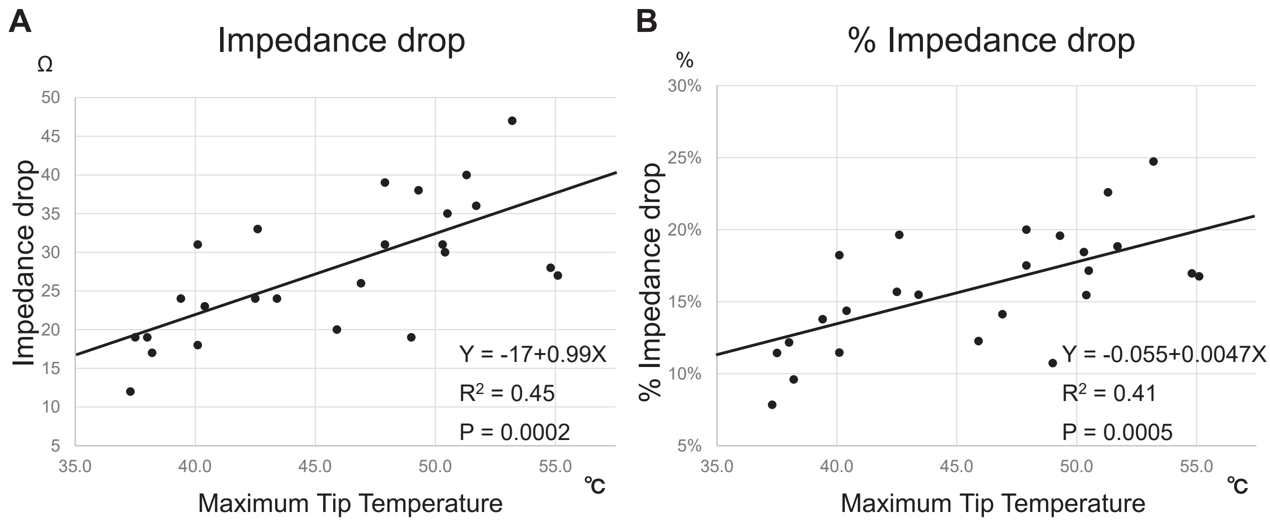

Figure 3 Correlation between the impedance drop and maximum tip temperature. **A:** Correlation between the impedance drop and maximum tip temperature. **B:** Correlation between the % impedance drop and maximum tip temperature.

embedded catheter tip. Although the usefulness and safety of the DTA system have been reported for atrial arrhythmia, there are limited reports on its use for ventricular arrhythmia ablation.[7,8] Al-Sheikhli and colleagues[9] reported that the number of VT episodes decreased in all 10 patients; however, steam popping and cardiac tamponade occurred in 1 patient at the default target temperature of 60°C and initial power of 50 W.

Based on previous reports of unipolar ablation using DTA, we performed bipolar ablation at target temperatures up to 55°C with careful monitoring of the generator impedance during the procedure. A total of 25 temperature-controlled bipolar ablations were performed, and no steam pops occurred. When we investigated the relationship between the generator impedance and tip temperature during each bipolar application, we found that there was a moderate correlation between the impedance drop and the maximum tip temperature, as there was with the %impedance drop ($R^2 = 0.45$, $P = .0002$ for impedance drop, $R^2 = 0.41$, $P = .0005$ for %impedance drop, Figure 3). The temperature of the DTA tip may reflect the tissue temperature of the ablation area in contact while the tip was cooled in the saline with these results. An impedance drop of approximately 20% was reached when the target temperature was set to 55°C; therefore, 55°C may be appropriate for bipolar ablation when temperature-controlled mode with DTA is used.

The length of the DTA tip is also considered to be an important factor in effective bipolar ablation in the present case. From a previous report by Younis and colleagues,[10] there is an inverse relationship between the contact surface area of the return electrode and circuit impedance, and increasing the contact surface area of the return electrode results in deeper and wider bipolar RF ablation lesions. In the present case, the DTA placed in the epicardium was in parallel contact with the myocardium. The tip length of the DTA is 4.1 mm, which is slightly larger than the conventional 3.5 mm tip and has a larger contact area. This difference in tip size may be related to clinical outcome of the present case.

Another important point in this case report is that DTA was used as an active catheter instead of a return catheter in order to use the temperature-controlled mode. To the best of our knowledge, this is the first report of temperature-controlled bipolar ablation using DTA as an active catheter, although there are reports stating that temperature monitoring of the return catheter is important during bipolar ablation.[3,5] Since the safety index for bipolar ablation has not been established, it may be possible to perform safer bipolar ablation by performing temperature-controlled ablation using DTA simultaneously as the impedance decreases. However, this is a single case report and limitations remain. First, the DTA's temperature sensor can only collect data from 1 side of the myocardium. Second, the temperature readings obtained from DTA may not match the intramural temperature during bipolar ablation. Further reports on the safety index of bipolar ablation are expected in large studies.

Conclusion

We experienced a case of VT in which bipolar RF ablation using temperature-controlled DTA was feasible. DTA can be effectively used as an active catheter for temperature control during bipolar ablation, in which case a target temperature of 55°C may be appropriate. Further elucidation of safety indicators is expected in prospective studies.

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