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Successful simultaneous unipolar radiofrequency ablation of septal ventricular tachycardia using 2 ablation catheters

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Case report

A 56-year-old man was transferred to our institution with incessant ventricular tachycardia (VT). He had been diagnosed with nonischemic cardiomyopathy and New York Heart Association class I congestive heart failure 15 years previously, and he had a single-chamber implantable cardioverter-defibrillator (ICD) placed for primary prevention. He had been maintained on sotalol 80 mg twice a day for several episodes of VT in the previous 2 years. One month before admission, he suffered an ICD shock for polymorphic VT/ventricular fibrillation, and amiodarone was added. At that time, an echocardiogram showed a left ventricular ejection fraction of 0.20 with global hypokinesis and an end-diastolic diameter of 7.2 cm and an interventricular septum thickness of 1.0 cm. One week before the transfer, he presented to the hospital after suffering 3 ICD shocks for VT at 188–194 beats/min that was unresponsive to antitachycardia pacing, in the setting of an argument with his brother. Intravenous amiodarone and lidocaine were administered in addition to sotalol, but he continued to experience VT episodes, resulting in 7 more shocks for VT. He was transferred to our hospital for further management.

On arrival to our intensive care unit, the patient's rhythm was sinus with a left bundle branch block pattern, but multiple sustained episodes of monomorphic VT occurred with a rate of 140–150 beats/min. The VT was not tolerated hemodynamically, frequently accelerated with antitachycardia pacing, and resulted in more ICD shocks. A representative 12-lead electrocardiogram tracing recorded during VT is shown in Figure 1, revealing that the VT had left bundle branch mimicry with inferior axis (a markedly different frontal axis from the QRS complex during sinus rhythm). Despite anesthesia with dexmedetomidine, endotracheal intubation, and placement of an intra-aortic balloon pump, his VT burden was not improved, and he received 18 shocks in a 24-hour period in our intensive care unit.

On the first attempt at catheter ablation, a combined endocardial/epicardial procedure was performed. Voltage mapping of the left ventricle during sinus rhythm showed a moderate-sized area of scar (defined as a bipolar voltage of <0.5 mV) along the interventricular septum from the base to the mid-ventricle; the epicardium was largely free of scar. Sustained VT was easily induced, and the earliest sites of activation during VT were identified along the left ventricular basal septum. Repeated unipolar radiofrequency (RF) energy delivery using 40 W, titrated up to 45 W, of duration 50 seconds, with an 3.5-mm open-irrigated ablation catheter (ThermoCool SF, Biosense Webster, Diamond Bar, CA) on both sides of the septum led to transient slowing of VT but never terminated the tachycardia during ablation. In addition, after RF application in the right ventricle, sustained complete heart block during sinus was noted with continued episodes of VT. Despite the extensive ablation performed in this region (>15 full lesions), on the night of the procedure 3 additional episodes of VT occurred that each required cardioversion. Several options were entertained at this point, including a repeat RF ablation attempt or an alcohol septal ablation (although no suitable candidate vessel was identified on coronary angiogram supplying the putative origin of VT). Also, expedited heart transplant evaluation was initiated by our heart failure colleagues and bridging to transplant with extracorporeal membrane oxygenation or a biventricular assist device was considered.

We reasoned that the VT most likely originated in an intramural site within the septum and the initial catheter ablation provided incomplete penetration into the mechanism, resulting in slowing but not elimination of the VT. We decided to perform a second attempt at catheter ablation, with the aim of producing lesions of greater depth. Venous and retrograde aortic access was obtained, and 2 separate ablation catheters were positioned on the left and the right side of the ventricular septum, respectively. The right-sided ablation catheter was an 8-mm catheter (Blazer II XP, Boston Scientific, Natick, MA), and the left-sided ablation catheter was a 3.5-mm open-irrigated catheter Diamond Bar, CA. Electroanatomic mapping was performed with CARTO 3 (ThermoCool SF, Biosense Webster, Diamond Bar, CA). Two separate dispersive patches were used as ground, with 2 separate generators in temperature (8 mm) and power (3.5 mm) controlled modes for the delivery of simultaneous unipolar radiofrequency (SURF) energy in a parallel configuration. This configuration allowed for independent temperature control and power control and, with separate return electrodes, did not require synchronization of RF current phases; essentially, this amounts to performing 2 simultaneous conventional RF ablations. A spontaneous initiation of VT was noted, and the earliest site of ventricular activation was once again mapped to the basal septum as identified on the previous procedure. Entrainment mapping was nondiagnostic, as it repeatedly transformed and accelerated the VT into a hemodynamically unstable rhythm that required cardioversion. The catheter positions in the left anterior oblique and right anterior oblique projections are shown in Figures 2A and 2B, alongside signals recorded from ablation catheters on the right ventricular septum and the left ventricular septum (Figure 2C). A diastolic potential was recorded preceding QRS onset by 51 ms on the left side of the septum and 25 ms on the right side of the septum, with a tachycardia cycle length of 400 ms. RF was applied at this site, using 55 W of energy via the 8-mm catheter (temperature controlled to 60°C) and 50 W of energy via the 3.5-mm catheter with standard irrigation rates. A smooth decline in the impedance curve was generated on the application

of RF current, and the full power was delivered (not capped by electrode temperature). The VT rate slowed during the application and then terminated. Two additional simultaneous lesions were delivered to consolidate lesion formation at the site of successful termination. At the conclusion of the case, VT was not inducible with double extrastimuli from either the right ventricular apex or the left ventricle despite multiple attempts (whereas it arose repetitively and spontaneously at the beginning of the case).

In addition to 1 ICD shock for a VT of different morphology and faster rate (~170 beats/min), which occurred during abrupt discontinuation of antiarrhythmic agents on the first postprocedural day owing to loss of central venous access, the patient remained VT-free during the remainder of his hospital stay. His ICD was upgraded to a cardiac resynchronization therapy device; his balloon pump was removed, and he was successfully extubated. His status on the transplant list was downgraded, and he was discharged to home 12 days after his second VT ablation. The patient had 2 isolated ICD shocks in the month after discharge for fast VT but has otherwise remained stable at home on an oral regimen of amiodarone and ranolazine.

Discussion

We present a case of incessant VT, who was initially unsuccessfully controlled with an attempt at endocardial catheter ablation and subsequently managed with SURF ablation with 2 ablation catheters on either side of the ventricular septum. To our knowledge, this is the first report of successful VT termination with SURF in a patient.

Previous work using animal models has established the theoretical basis for this technique in multi-electrode preparations,¹⁻⁴ in addition to experience with the pulmonary vein ablation catheter used for the treatment of atrial fibrillation.⁵ The Stevenson group applied bipolar RF and SURF using 6-F electrodes on the bovine myocardium in a saline bath.³ Both bipolar configuration and SURF led to dramatically larger lesion sizes compared with sequential applications. There was a relative advantage of bipolar application over SURF, which disappeared when 1 electrode was not sufficiently in contact with tissue.³ However, these studies were limited in that ablation electrode configuration and spacing differed from clinically employed ablation catheters and/or did not attempt ablation along opposing surfaces of the myocardial wall.

In conventional unipolar RF, a circuit is formed from the catheter tip to the dispersive grounding pad as the return electrode, with larger power density at the catheter tip due to the smaller surface area of the ablation electrode compared to the cutaneous grounding patch. Bipolar ablation with clinically employed ablation catheters has the theoretical advantage of more effective power transfer from catheter tip to catheter tip, providing the basis for deeper lesion formation on subsequent pathologic examination compared to 2 separate unipolar applications.^{6,7} Lesion depth in bipolar ablation is critically dependent on achieving sufficiently high current density in the vicinity of each catheter tip, which is a complicated function of catheter geometry, electrode spacing, and orientation. Our approach using SURF ablation differs in that intramural heating is dependent on (1) unipolar resistive tissue heating at each catheter-myocardium interface (which can be optimized by tissue contact

force and power delivery) and (2) conductive heating to the midpoint of the muscle wall from opposing directions. Ablation along the right ventricle produces another heat “source” that can be expected to produce higher intramural tissue temperatures during an application by conductive heat transfer. We therefore speculate that SURF ablation creates lesion characteristics distinct from other configurations of RF energy delivery. The comparative efficacy of SURF vs bipolar ablation in clinically relevant situations is lacking, but is worthy of further study in appropriate animal and computational models, such as finite element modeling. One practical advantage of SURF ablation is that it is a technique that can be more easily applied (provided 2 RF generators are available, using commercially available ablation catheters and without a need for a specifically engineered cable to attach the return electrode to the generator).

Despite minimal characterization in the literature, we performed this ablation under emergent circumstances, as the nature of the patient’s VT storm presented substantial risks of hemodynamic deterioration and death, or requirement of the initiation of mechanical support, with its attendant risks. While it was successful in our case, several limitations are inherent to this technique. We cannot exclude the possibility that alternate factors may have enhanced our success in the second procedure, including subtly different catheter positioning (although extensive ablation was performed at different sites in the first procedure), slightly different programmed powers, and the possibility that some degree of scar was formed in the first procedure that permitted more efficient heat transfer during the second procedure. It is also important to note that theoretical risks are increased with SURF, chiefly the risk of excessive superficial tissue heating, which translates into not only a higher risk of char formation or steam pops but also perforation/ventricular septal defect formation, and development of heart block when applied to the ventricular septum. In our procedure, we carefully monitored the biophysical parameters of lesion delivery including power delivery, local electrode temperatures on either side of the septum, and impedance profiles for each simultaneous lesion and saw no evidence of excessive local tissue heating. Finally, we cannot state with certainty that the generated lesions were symmetric and completely opposed and abutting each other. We attempted to align catheter tips by using electroanatomic mapping to localize our left-sided ablation catheter while ensuring apposition of ablation catheter tips on either side of the septum with fluoroscopy, as shown in Figure 2. We believe that the larger 8-mm electrode may have provided a safety margin for catheter positioning.

Conclusions

We present a case of successful termination of VT with SURF ablation with use of 2 ablation catheters, with effective control of VT storm permitting hospital discharge. We believe that this technique may be useful in cases of suspected intramural origin of tachycardia (between epicardial and endocardial surfaces, or within the septum as in this case) in order to provide deeper penetration of created lesions compared with sequential unipolar ablation, although the characteristics of lesion formation (especially in comparison with other configurations such as bipolar ablation) merit further study.

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ABBREVIATIONS

ICD	implantable cardioverter-defibrillator
RF	radiofrequency
SURF	simultaneous unipolar radiofrequency
VT	ventricular tachycardia

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Figure 1. Twelve-lead electrocardiograms recorded during (A) ventricular tachycardia and (B) sinus rhythm before ablation.

Figure 2.

A and B Simultaneous radiofrequency ablation with use of 2 ablation catheters: right anterior oblique projection, 30° (panel A); left anterior oblique projection, 45° (panel B). **C:** Intracardiac recordings reveal diastolic potentials recorded from both ablation catheters preceding the surface electrocardiogram during ventricular tachycardia. Abl = ablation; L = left; R = right; RV = right ventricle.