Approach to Ablation of Unmappable Ventricular Arrhythmias

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KEYWORDS

• Ventricular tachycardia • Catheter ablation • Substrate mapping

KEY POINTS

- Most patients with structural heart disease referred for ventricular tachycardia (VT) ablation have unstable tachycardias not suitable for conventional mapping (ie, entrainment mapping).
- Substrate-guided mapping and ablation during sinus rhythm are intended to overcome the limitations of conventional mapping and ablation.
- Substrate ablation permits elimination of multiple VTs irrespective of their inducibility during the procedure or their hemodynamic tolerability.
- Elimination/isolation of the arrhythmogenic substrate identified during sinus rhythm has been associated with better outcomes.
- There is currently no standardized approach for substrate-guided ablation.

INTRODUCTION

Catheter ablation has increasing utility in treating patients with ventricular arrhythmias. It can control arrhythmic storm and reduce shocks in implantable cardioverter-defibrillator (ICD) recipients, and indications for ablation of ventricular tachycardia (VT) in patients with structural heart disease have expanded. Randomized clinical trials have shown that prophylactic catheter ablation before secondary prevention ICD implant reduces the incidence of appropriate device therapy.[1,2] Radiofrequency (RF) catheter ablation using a percutaneous approach for the treatment of ventricular arrhythmias has made significant progress over the past 2 decades. From conventional mapping techniques based on pacing maneuvers during tachycardia and ablation guided by fluoroscopy, to preprocedural cardiac imaging and the use of electroanatomic mapping systems for substrate-guided approaches, many advances in techniques and technologies have provided a better understand of the substrate of ventricular arrhythmias and improved ablation outcomes. Nonetheless, postablation recurrence rates remain high.[3]

MECHANISM OF SCAR-RELATED VENTRICULAR TACHYCARDIA AND CONVENTIONAL MAPPING

Scar-related reentry is the most common mechanism involved in the genesis of sustained

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monomorphic VTs (SMVT) in patients with structural heart disease. The most studied reentry model is the healed myocardial infarction. Classic histologic studies showed that slow conduction zones corresponded with viable fibers embedded between areas of fibrosis.[4,5] Gap junction abnormalities (changes in connexin distribution), autonomic nervous system imbalance, and loss of ion channel function can also contribute to slow conduction.[6] The substrate of ventricular arrhythmias in nonischemic cardiomyopathy is less well known. The presence of scars containing replacement fibrosis and the survival of fibers overlapping diseased tissue provide the perfect place for reentrant arrhythmias.

The critical part of the reentry circuit within the scar is known as tachycardia isthmus. The isthmus is the narrowest portion of the circuit and is a viable corridor surrounded by scar tissue. Several studies have shown that the tachycardia isthmus is usually found within the dense scar.[7,8] In some cardiomyopathies, and specifically in inferior infarctions, the tachycardia isthmus is located between the scar and the mitral annulus (submitral isthmus). In this case, the valve ring forms a fixed barrier conduction block. The postsurgical scars can also behave as barriers and facilitate the formation of reentry circuits.

Activation mapping, pace mapping, and entrainment mapping are conventional techniques used in SMVT ablation. In focal arrhythmias, activation and pace mapping techniques are preferred. In the case of reentrant VT, entrainment mapping is the most appropriate,[9] allowing identification of the reentry circuit's entrance, exit, isthmus sites, outer loop/inner loop, and bystanders.[10] RF ablation at isthmus sites usually terminates SMVT.[11] When VTs are poorly tolerated, noninducible, or nonsustained, pace mapping is the preferred approach. Although pacing from the tachycardia exit (the point from which the electrical activity during VT emerges to activate the whole ventricle) can, in theory, reproduce the QRS morphology of the VT, the paced QRS at isthmus sites can be manifestly different in macroreentrant VTs because the paced wave front propagates retrogradely in the opposite direction to that of the VT wave front. Only a minority of patients (10%) with structural heart disease have sufficiently stable and hemodynamically tolerated VTs to permit detailed conventional mapping.[12,13]

SUBSTRATE MAPPING

Novel ablation techniques have been proposed to overcome the limitations of conventional mapping and ablation. The main objective of these techniques is to characterize and eliminate the arrhythmogenic substrate during stable rhythms. Substrate-guided mapping and ablation are possible thanks to the incorporation of navigation systems into electrophysiology laboratories. These nonfluoroscopic systems permit electroanatomic reconstructions of the myocardial scar and ventricles and facilitate labeling of target sites during sinus rhythm.

This approach allows ablation of multiple VT morphologies irrespective of their inducibility or hemodynamic tolerability. It is generally accepted that substrate-guided mapping implies a more extensive ablation. The substrate analysis can be combined with conventional ablation techniques to limit the study area and facilitate mapping. There is currently no standardized technique for mapping and ablation of VT substrate; multiple approaches are used that differ to a greater or lesser extent in the mapping technique and ablation targets.

The first approach to substrate-guided mapping emerged from accumulated experience with surgery for ventricular arrhythmias. In the 1970s, surgical resection guided by preoperative or intraoperative mapping was shown to abolish VT in patients with healed myocardial infarction.[14] When an extended endomyocardial resection was performed, intraoperative conventional mapping was not necessary. In a large surgical series, the postoperative inducibility of VT was similar irrespective of intraoperative mapping.[15] Marchlinski and colleagues[16] proposed the creation of linear ablation lines extending through the border zone (bipolar voltage, 0.5–1.5 mV) from the dense scar (<0.5 mV) to the normal myocardium or anatomic boundary (ie, mitral ring). In order to reduce RF energy delivered, electrocardiogram morphology during VT and pace mapping were also used to focus on the scar area of interest.[16]

TECHNIQUES AND TARGETS FOR SUBSTRATE-GUIDED ABLATION

After the initial description, various approaches and targets (ie, surrogates of VT isthmuses) have been described for substrate-guided ablation (**Fig. 1**, **Table 1**).[17–24] Initially restricted for unmappable VT, substrate-guided ablation has become a cornerstone of the catheter treatment of complex ventricular arrhythmias.

Linear Ablation and Pace Mapping

Bipolar voltage maps allow the identification of scar tissue. The most accepted cutoff value for normal myocardium is 1.5 mV.[16] Viable myocardial fibers can survive within the dense scar (0.5 mV).[25]