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## Interventricular septal substrates for scar-related monomorphic ventricular tachycardia

### 1. Intramural substrates for scar-related VT

Ablation for scar-related ventricular tachycardia (VT) relies on the identification and controlled destruction of arrhythmogenic substrates within areas of patchy or confluent fibrosis [1]. The distribution of arrhythmogenic scars can vary based on etiology, and may be subendocardial, sub-epicardial, or intramural with variable extent, sometimes occupying the entire thickness of the ventricular wall. Ablation is most successful when the scar and substrate are predominantly subendocardial as is common with ischemic VTs. Sub-epicardial substrates are more common in the non-ischemic and genetic arrhythmogenic cardiomyopathies necessitating epicardial mapping and ablation in over a third of cases. Intramural substrates are more difficult to access as normal myocardium of variable thickness may overlie them, hindering adequate mapping and ablation. Local electrogram features indicative of delayed conduction, tissue uncoupling and diastolic corridors during VT can be difficult to detect when the substrates are intramural. In such situations, mapping deep within the myocardium with the use of a needle electrode can demonstrate favorable electrograms when none are evident on the endocardial surface [2]. Catheter-based radiofrequency ablation lesions on the endocardium are limited to depths of 5–7 mm and inability to reach deeper substrates is a common reason for arrhythmia recurrence after ablation.

One site for deep VT substrates is the inter-ventricular septum, an area that is commonly involved in both the ischemic and non-ischemic cardiomyopathies. The nature of the scar, however, tends to vary. Infarct-related septal scars are usually endocardial and associated with wall thinning. Intramural septal fibrosis is less common, detectable in only 11% in one series [3]. However, reperfusion therapy for ST elevation myocardial infarction that is highly effective in myocardial salvage has altered these substrate characteristics. Less homogenous and more patchy involvement may be seen, occasionally limited to the mid-myocardium [4]. Unlike the infarct related scar, the pattern of fibrosis in the non-ischemic cardiomyopathies is less clearly defined. Patchy areas of fibrosis in the perivalvular basal myocardium in a non-coronary distribution, is a common histological finding. Two predominant patterns of scar distribution are recognized in patients who present with monomorphic VT: one involving the peri-mitral basal inferior lateral LV wall, and the second, in the anterior infra-aortic LV and septum. Both patterns may co-exist. Septal fibrosis and substrates for VT are common, occurring in close to 80% of patients [5].

### 2. Identification of septal scar

Identification of septal substrates informs ablation strategies and approach to the ventricular chambers. VTs exiting from the septum tend to display a left bundle branch block pattern in V1. When the exit involves the high septum, precordial QRS transition is early, usually before V3. Early engagement of the conduction system may result in relatively narrow QRS during VT. Pre-procedural contrast enhanced magnetic resonance imaging (CMR) is perhaps the most useful method for detection of septal fibrosis that may be silent to contact mapping, although the presence of implanted cardiac devices often limits image quality. Intra-procedurally, electroanatomic mapping along the septum typically demonstrates normal bipolar voltages but low unipolar voltages when the scar is intra-mural. In one study, a unipolar voltage <4.8 mV recorded on the left ventricular (LV) side of the septum correlated with CMR detected intramural septal scar [5]. In addition, when pacing on the right ventricular side of the septum, the recording of delayed activation (>40 ms) and fractionated electrograms with more apical exits on the LV side is highly suggestive of septal scar [6]. Successful ablation of these septal substrates often requires deeper ablation lesions. Various techniques have been described to access these intramural locations. These include the use of higher impedance saline (half normal saline) for open irrigation during RF application, sequential ablations from the right and left ventricular aspects of the septum, dual site unipolar ablations using two RF generators, simultaneous bipolar ablation, *trans*-coronary arterial ethanol ablation, ablation via the coronary venous branches and the use of investigational needle ablation catheters [2,7].

### 3. The present study of VT ablation with septal scar

In this issue of the journal, Halbfass et al. provide retrospective observations on acute and mid-term success rates of VT ablation from centers in Germany [8]. In a cohort of 199 consecutive patients (55% with ischemic cardiomyopathy), 65% were assessed to have VT substrates in the interventricular septum. The distribution of septal involvement was not significantly different between ischemic and non-ischemic patients. Compared to the group without septal involvement, patients with septal substrates has a lower acute procedural success rate (80% versus 94%,  $p = 0.007$ ). During a mean follow up period of 8 months, VT recurrence tended to be higher (39% vs 25%,  $p = NS$ ) in patients with septal substrates. When a VT with a presumed septal isthmus was induced, acute success defined as suppression of any inducible VT, was significantly lower. Recurrence rates were no different between ischemic and non-ischemic substrates. These observations extend the available

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information on septal scar substrates for VT and confirm the difficulties in successful suppression of re-entrant VT when the critical isthmus for re-entry is located within the septal musculature.

Published literature and our own experiences with septal substrates for VT suggest that ischemic substrates have a higher ablation success rate by virtue of their endocardial nature and associated wall thinning. Septal substrates in the non-ischemic cardiomyopathies, on the other hand, are more likely to reside in the mid-myocardium necessitating additional ablation approaches. The present study observed equivalent success for both types of cardiomyopathies despite the high prevalence (65%) of septal involvement. It should be recognized that defining the septum is not necessarily straight forward and likely varies among studies. This study primarily relied on electroanatomic (EAM) mapping to define the interventricular septum. Unless both RV and LV EAMs are simultaneously displayed, the exact septal boundaries can be difficult to define. Only half of patients in the present study had a preprocedural imaging study with CT or CMR. It is possible that more substrates were assigned to a septal location in the present study than might be defined based on CMR imaging that can be registered in the EAM. Another limitation of the study is that the follow-up period was relatively short; more recurrences might be observed with longer follow-up.

#### 4. What is the optimal strategy for ablation of septal VT substrates?

Despite the frequent septal substrates and a trend for more recurrences in patients with septal substrate, the outcomes were good in the current study. The optimal approach to ablating septal substrate is not clear and the author's approach is of interest. The authors generally used unipolar ablation from the LV side of the septum; bipolar ablation was used in only 1 patient and ablation from both the RV and LV in only 11% of those with septal substrate. They ablated at 45 W targeting an ablation index value of 700–1000. The ablation index (AI) combines time, power and contact force into a single value and has been well studied in the atrium and used for pulmonary vein isolation. How it relates to ablation in thicker tissue of the ventricles is less well defined. In an ovine model, AI appeared to correlate better with volume than lesion depth [9]. A prior study used an AI value of 490 for the RVOT free wall and 610 for the RVOT septum with good results and no complications [10]. The author's approach in the current study appears likely to achieve deep lesions. However, in view of studies suggesting that long applications facilitate lesion depth, further investigation of parameters for optimal RF delivery for septal substrate is needed. In the ovine model, the AI did not correlate with lesion size when half normal, rather than normal saline was used for irrigation [9].

#### 5. Where do we stand with ablation for scar-related VT?

Given the heterogenous nature of VT substrates and ablation techniques, prospective randomized trials of VT ablation are difficult to conduct. In this context, observational studies such as the present study, add to our current understanding. The authors should be lauded for achieving a 70% freedom from recurrent VT at 8 months in this population with both ischemic and non-ischemic cardiomyopathies. Randomized trials of VT ablations have consistently shown a reduction in implanted defibrillator shocks and VT storm, a major quality-of-life metric for patients, in addition to excellent safety [11]. Improvement in other outcome metrics have been difficult to demonstrate consistently. However, better understanding of the nature of VT substrates coupled with

advances in ablation technology is expected to continue to improve success rates and outcomes with VT ablation. Preliminary results from the recent prospective randomized PAUSE-SCD trial suggests an 80% VT non-inducibility with ablation in a population with both ischemic and non-ischemic cardiomyopathy [12]. All of these newer data demonstrating higher success rates suggest that we have arrived at a point in the development of non-pharmacological control where it is no longer necessary to exhaust all antiarrhythmic drug options before consideration of referral to specialized centers for ablation for recurrent VT.

#### Declaration of competing interest

Roy M. John: Lecture Honoraria – Abbott Inc, Medtronic Inc.  
William Stevenson: Lecture Honoraria: Abbott, Medtronic, Johnson and Johnson, Boston Scientific, Media Sphere, Biotronik.  
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