In silico Comparison of Substrate-based Ablation Strategies in Structural Ventricular Tachycardia

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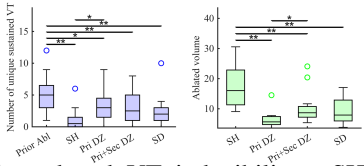
Aim: Substrate-based catheter ablation is a cornerstone therapy for ventricular tachycardia (VT) in structural heart disease, but different ablation strategies vary in efficacy and myocardial damage. This study aimed to quantitatively compare commonly used and emerging substrate-based VT ablation strategies using patient-specific in silico models.

Methods: Cardiac electrophysiology models were generated from late gadolinium enhancement cardiac magnetic resonance (LGE-CMR) data from 15 patients with ischemic or non-ischemic cardiomyopathy. Starting from LGE-CMR, patient-specific computational models were generated including scar and border zone architecture, fiber orientation, and Purkinje activation. Four substrate-based ablation strategies were virtually implemented: scar homogenization (SH), primary deceleration zone (DZ) ablation, primary plus secondary DZ ablation, and CMR-guided scar dechanneling (SD). Virtual ablation lesions were applied using an interactive platform, and VT inducibility was systematically assessed using standardized stimulation protocols before and after ablation. Strategy performance was evaluated based on residual inducible VT circuits and ablated myocardial volume.



Results: At baseline, sustained VT was inducible in 12 of 15 patients, with 63 unique reentrant circuits identified (5.25 VTs per inducible patient). All ablation strategies significantly reduced VT inducibility. SH achieved the largest efficacy, reducing residual inducible VTs to 1.17 per patient, but required the largest ablation volume. CMR-guided SD reduced inducible VTs to 2.42 per patient with a substantially smaller ablation volume. Primary DZ ablation resulted in limited VT suppression (3.5 residual VTs per patient) but minimized ablated tissue, while adding secondary DZ ablation improved efficacy (2.92 residual VTs per patient) at the cost of increased ablation volume. When normalized to ablated tissue, SD showed the highest efficiency.

Conclusion: Our study reveals marked differences among substrate-based VT ablation strategies. Selective approaches such as CMR-guided SD and DZ-based ablation provide favorable trade-offs between VT suppression and myocardial preservation.