CATHETER ABLATION OF VENTRICULAR TACHYCARDIA: CURRENT STATUS

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I PATHOPHYSIOLOGY AND THE MYOCARDIAL SUBSTRATE DIVIDE

- **Ischemic Cardiomyopathy (ICM — Post-Myocardial Infarction Scar):**
  - **Mechanism: Anatomical Macro-Reentry** through surviving bundles of viable myocytes insulated by dense collagen scar (forming slow-conduction **critical isthmus channels** with entry, central, and exit sites).
  - **Anatomical Location and Access:** Follows the wavefront of coronary occlusion—predominantly **subendocardial** (progressing toward the epicardium), making the substrate directly accessible via **endocardial catheter ablation** (via retrograde transaortic and/or transseptal LV access) with **high acute and long-term success (70 to 85 percent)**.
  - **Non-Ischemic Cardiomyopathy (NICM — DCM, Sarcoidosis, Myocarditis, ARVC, Chagas):**
  - **Mechanism:** Macro-reentry around patchy, non-confluent replacement fibrosis.
  - **Anatomical Location and Access:** Scars cluster preferentially in two regions: (1) **Perivalvular basal anteroseptal (interventricular septum)** or (2) **Basal inferolateral mid-myocardium and subepicardium** (sparing the subendocardium). Consequently, endocardial RF lesions often fail to reach the circuit, requiring **combined endocardial and percutaneous subxiphoid epicardial ablation (Sosa technique)** or bipolar/needle/alcohol ablation, with lower long-term freedom from VT (**50 to 65 percent**).
  - **Idiopathic Ventricular Tachycardia (Structurally Normal Hearts):**
  - **Outflow Tract VT (RVOT [80%] & LVOT/Aortic Cusps [20%]):** Driven by **cAMP-mediated triggered activity (Delayed Afterdepolarizations [DADs])**; **LBBB morphology with inferior axis (+90 degrees)**; sensitive to vagal maneuvers, Adenosine, Beta-blockers, and Verapamil.
  - **Idiopathic Left Ventricular Fascicular VT (Belhassen VT):** Driven by **calcium-channel-dependent macro-reentry involving the Left Posterior Fascicle (90%)** and abnormal Purkinje tissue; **narrow QRS (120–140 ms) RBBB morphology with superior Left Axis Deviation** (or Left Anterior Fascicle: RBBB + Right Axis Deviation); **uniquely Verapamil-sensitive**.
  - **Outcome:** Catheter ablation is **definitively curative in >90 to 95 percent (Class I first-line)**.

II EVOLUTION OF MAPPING TECHNIQUES IN STRUCTURAL HEART DISEASE

- **Limitations of Activation and Entrainment Mapping During VT:** Classical activation mapping (finding mid-diastolic potentials) and **concealed entrainment** (pacing during VT with post-pacing interval minus tachycardia cycle length <=30 ms and stimulus-to-QRS = electrogram-to-QRS) require the patient to tolerate sustained VT. However, **>70 to 80 percent of scar-related VTs are hemodynamically unstable**, multiple, or non-inducible under anesthesia.
- **Modern Gold Standard — Sinus-Rhythm / Paced 3D Substrate Mapping:**
  - **Bipolar and Unipolar Voltage Mapping:** Using high-density multipolar mapping catheters (PentaRay, OctaRay, HD Grid), **Bipolar voltage <= 0.5 mV** defines **dense endocardial scar**, **0.5 to 1.5 mV** defines the **scar border zone**, and **>1.5 mV** defines **normal myocardium**. Crucially, a normal endocardial bipolar voltage (>1.5 mV) with a **reduced Unipolar LV voltage (<8.3 mV; or <5.5 mV in the RV)** unmasks **deep intramural or epicardial scar**!
  - **Functional Substrate Targets (ILAM, Late Potentials, LAVA, and Core Isolation):** Operators target **Late Potentials (LPs)** (potentials occurring after the surface QRS offset), **Local Abnormal Ventricular Activities (LAVAs)** (high-frequency fractionated potentials decoupled by extrastimuli), and **Isochronal Late Activation Mapping (ILAM)** deceleration zones (**"Scar Homogenization / Dechanneling"**), achieving complete **non-inducibility of any VT on programmed electrical stimulation (the procedural endpoint)** without prolonged hemodynamic instability.
  - **Pre-Procedural Contrast CT (MUSIC / inHeart) and Late Gadolinium CMR Integration:** Imports 3D CMR scar channels and CT wall-thinning/coronary/phrenic nerve anatomy directly into the 3D mapping system.

III LANDMARK RANDOMIZED TRIALS SUPPORTING EARLY VT ABLATION

Landmark Trial	Patient Population & Comparison	Primary Efficacy Outcome	Paradigm Impact
VANISH (2016) (*NEJM*)	**259 ICM** patients with ICD & VT despite baseline AAD (Amiodarone or Sotalol): **Catheter Ablation vs. Escalated Drug Therapy**	**28% RRR in primary composite** (death, VT storm, or appropriate ICD shock: **59.1% vs. 68.5%; HR 0.72; p = 0.04**), driven by patients failing **Amiodarone** (HR 0.53)	Established **Class I** indication for ablation over escalating AADs when **Amiodarone fails** in ICM
VANISH2 (2024) (*NEJM* Nov 2024)	**416 ICM** patients with VT and NO prior AAD failure: **First-Line Catheter Ablation vs. First-Line Sotalol or Amiodarone**	**25% RRR in primary composite** (death, VT storm, appropriate ICD shock, or sustained VT: **50.7% vs. 60.6%; HR 0.75; p = 0.03**) with fewer non-fatal adverse events	Proved **First-Line Catheter Ablation is superior to starting Amiodarone/Sotalol** in post-MI VT
PARTITA (2022) (*Circulation*)	**Ischemic & Non-Ischemic** ICD patients: **Immediate VT Ablation after FIRST Appropriate ICD Shock vs. Standard Waiting**	**89% RRR in primary composite of All-Cause Death or Worsening HF Hospitalization** (**4% vs. 42%; HR 0.11; p = 0.01**) + fewer recurrent shocks (**9% vs. 42%**)	Shifted VT ablation to **after the very first ICD shock** to prevent HF progression and mortality
PAUSE-SCD (2022) (*Circulation*)	**121 Asian ICM, NICM, & ARVC** patients (54% NICM/ARVC) undergoing ICD: **Upfront Ablation at ICD Implant vs. Medical Therapy**	**42% RRR in primary composite** (VT recurrence, CV hospitalization, or death: **49.3% vs. 65.5%; HR 0.58; p = 0.04**)	Proved early ablation efficacy in **Asian NICM and ARVC** cohorts

Landmark Trial	Patient Population & Comparison	Primary Efficacy Outcome	Paradigm Impact
SURVIVE-VT (2022) & **BERLIN VT (2020)**	**SURVIVE-VT (144 ICM): First-line Ablation vs. AAD**; **BERLIN VT:** Preventive ablation *before* any shock vs. deferred until 3rd shock	**SURVIVE-VT: 48% RRR** in CV death, shock, HF admission, or severe treatment complication (**28.2% vs. 46.6%; HR 0.52**); **BERLIN VT:** Neutral primary endpoint (stopped early for futility)	Supports ablation at first clinical VT/shock (rather than purely prophylactic before any clinical VT)

IV CURRENT GUIDELINE RECOMMENDATIONS (ESC 2022 VA/SCD GUIDELINES)

- **Class I Recommendations (Recommended):**
  - **Symptomatic Idiopathic Outflow Tract (RVOT) or Fascicular (Belhassen) VT:** First-line therapy.
  - **Ischemic Cardiomyopathy with Recurrent Symptomatic Sustained Monomorphic VT or ICD Shocks Despite Chronic Amiodarone Therapy:** Catheter ablation is recommended over escalating antiarrhythmic drug therapy (**VANISH**).
  - **Incessant VT or Electrical Storm** resulting from sustained monomorphic VT refractory to antiarrhythmic drugs.
  - **Bundle-Branch Reentrant VT (BBR-VT)** (seen in DCM, myotonic dystrophy, or post-aortic valve surgery; cured by ablating the **Right Bundle Branch**).
  - **Class IIa Recommendations (Should Be Considered):**
  - **Ischemic Cardiomyopathy with Recurrent VT on Beta-Blockers or Sotalol** (when Amiodarone is not desired; further strengthened by **VANISH2**).
  - **Ischemic Cardiomyopathy After a First Episode of Sustained Monomorphic VT / First Appropriate ICD Shock** (**PARTITA, SURVIVE-VT**).
  - **Non-Ischemic Cardiomyopathy (DCM / ACM / ARVC) with Recurrent Symptomatic Sustained Monomorphic VT or ICD Shocks** in specialized centers with epicardial ablation capability when antiarrhythmic drugs are ineffective, contraindicated, or not tolerated.

V PRACTICAL CONSIDERATIONS IN THE INDIAN CLINICAL CONTEXT

- **High Prevalence of Verapamil-Sensitive Fascicular VT (Belhassen VT):** In young Indian adults with structurally normal hearts, **Left Posterior Fascicular VT** (**RBBB morphology + Left Axis Deviation + RS interval <80 ms + capture/fusion beats**) is frequently misdiagnosed in emergency departments as **"SVT with aberrancy"** (because the QRS is relatively narrow at 120 to 140 ms and terminates with IV **Verapamil** while being unresponsive to Adenosine). Catheter ablation targeting **purkinje potentials (P1 diastolic and P2 pre-systolic potentials)** along the inferoposterior LV septum offers a >95 percent permanent cure.
- **Granulomatous Substrates (Cardiac Sarcoidosis and Tuberculous Myocarditis):** In India, non-ischemic monomorphic VT frequently arises from **Cardiac Sarcoidosis** or healed **Tuberculous Myopericarditis**. Active myocardial inflammation must first be excluded via **18F-FDG PET/CT** and suppressed with corticosteroids/anti-tubercular therapy before attempting catheter ablation (which frequently requires **combined endocardial and epicardial access**).
- **Late-Presenting Anterior STEMI Apical Aneurysms:** Delayed STEMI reperfusion in rural India leads to large calcified **LV apical aneurysms** with mural thrombus; **pre-procedural Contrast Echo or Cardiac CT/MRI** is mandatory before endocardial LV mapping to exclude **mobile LV thrombus** (an absolute contraindication to endocardial LV ablation, though epicardial ablation remains feasible).

VI FRONTIER MODALITIES FOR REFRACTORY INTRAMURAL VT

- **Intramural Septal Bailout Techniques:** When the VT circuit is buried deep inside a thick interventricular septum (>10–15 mm), specialized techniques include **half-normal (0.45%) saline irrigation** (increases impedance to create deeper RF lesions), **Simultaneous Unipolar or Bipolar RF Ablation** (between RV and LV septal catheters), **Retractable Intramyocardial Needle Ablation**, **Transcoronary / Transvenous Ethanol Septal Ablation**, and **Pulsed Field Ablation (PFA)** (non-thermal electroporation that penetrates fibrous scar with relative sparing of the phrenic nerve, though coronary spasm can occur).
- **Non-Invasive Stereotactic Body Radiation Therapy (SBRT / Cardiac Radioablation — ENCORE-VT):** A single **25-Gray fraction** of external-beam stereotactic radiotherapy guided by non-invasive ECG-imaging (ECGI) and CT/CMR reduces VT burden by >85–90% as a compassionate bailout in patients with refractory electrical storm unsuitable for catheter ablation.

KEY REFERENCES

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