Ventricular Tachycardia: Catheter Ablation

Who? How? When? Results?

Vivek Y. Reddy, MD
Helmsley Trust Professor of Medicine
Director, Cardiac Arrhythmia Service
The Mount Sinai Hospital

vivek.reddy@moundsinai.org
Disclosures

• **Grant support and/or Consultant:**
  – Abiomed Inc, Biosense-Webster Inc, Stereotaxis Inc, St Jude Medical Inc

• I will be discussing off-label use of catheter ablation devices.
• Scar-Related VT Ablation
• Outflow-Tract VT/PVCs
• Ventricular Fibrillation
• Scar-Related VT Ablation
• Outflow-Tract VT/PVCs
• Ventricular Fibrillation
Pathogenesis of Scar-Related VT

- Electrically-active live myocardial fibrils traversing through the fibrotic tissue of the scar
Post-MI VT: Catheter Ablation

- Post-MI VT is not a simple substrate with a single circuit

- Better to think of post-MI VT as an arrhythmogenic mass of tissue from which multiple VTs can emanate

- For clinical success need to treat not as circuits but as substrate

Downar et al, JACC 1998
1. Target Channels for Ablation
2. Target VT Exit Sites
Substrate Mapping & Ablation

3. Homogenize Scar

The VISTA Trial


P < 0.001

Freedom from VT

Isthmus Ablation  Substrate Ablation
Substrate Ablation of Unstable VT

Single & Multicenter Studies


Stevenson at al, *Circulation* 2009
Multicenter Thermocool VT Ablation IDE Trial

Long-Term Outcomes

Coronary Artery Disease → + Recurrent VT → ICD Shocks

Open-Irrigated VT Catheter Ablation (249 Patients) → No Procedure-Related Strokes

Long-Term Outcome
Percentage with ICD Shocks

Pre-Ablation → 6 months → 1 Year → 2 Years → 3 Years

Post-ablation

↓ Anxiety Score (6 Months)
↓ Amiodarone Requirement (6 Months-3 Years)
↓ Hospitalizations (6 Months-3 Years)


VANISH: Post-MI VT
RCT: AADs vs Catheter Ablation

Primary Prevention of ICD Shocks

**SMASH-VT**

Preventative substrate ablation in preventing ICD shocks in post-MI pts who have sustained a VT/VF event (ie, 2° prevention ICD pts)

- **History of a MI**
  - Cardiac Arrest (VT/VF)

- **Randomization**

- **ICD**
- **ICD + Substrate Ablation**

- **Follow-Up (2 years)**


**ICD “Storm” Occurrence**
- 6% vs 19%
- $P = 0.06$

<table>
<thead>
<tr>
<th>Freedom from ICD Rx (%)</th>
<th>Ablation</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follow-Up (Months)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>82.8</td>
</tr>
<tr>
<td>12</td>
<td>100</td>
<td>84.6</td>
</tr>
<tr>
<td>18</td>
<td>100</td>
<td>84.6</td>
</tr>
<tr>
<td>24</td>
<td>91.8</td>
<td>15.6</td>
</tr>
</tbody>
</table>

$P = 0.003$
Can catheter ablation reduce VT/VF in post-MI patients undergoing ICD implantation for stable VT?

- History of a MI
- Stable VT
- LVEF < 50%

Randomization

- ICD
- ICD + Ablation

Follow-Up (2 years)

Catheter Ablation in DCM-VT
Moderate Success (Compared to Post-MI VT)

VT-free Survival at 1 year:
ICM = 57%, NICM = 40.5%

For DCM-VT, the only predictors of VT recurrence were “Partial Success” or Failure.

Table 4. Multivariable Regression Analysis for the VT Recurrence in NIDCM and ICM

<table>
<thead>
<tr>
<th></th>
<th>NIDCM, HR; 95% CI</th>
<th>P Value</th>
<th>ICM, HR; 95% CI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.96; 0.95–1.015</td>
<td>0.278</td>
<td>0.97; 0.95–0.99</td>
<td>0.038</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>1.3; 0.77–2.24</td>
<td>0.313</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart failure, NYHA class I–IV</td>
<td>1.02; 0.63–1.66</td>
<td>0.929</td>
<td>1.36; 1.02–1.81</td>
<td>0.034</td>
</tr>
<tr>
<td>EF, %</td>
<td>1.003; 0.97–1.03</td>
<td>0.853</td>
<td>0.98; 0.96–1.007</td>
<td>0.172</td>
</tr>
<tr>
<td>Failure vs complete success</td>
<td>4.12; 1.56–10.89</td>
<td>0.004</td>
<td>4.48; 1.2–16.65</td>
<td>0.025</td>
</tr>
<tr>
<td>Partial vs complete success</td>
<td>3.28; 1.25–8.65</td>
<td>0.016</td>
<td>1.9; 1.004–3.58</td>
<td>0.048</td>
</tr>
<tr>
<td>No. of VTs</td>
<td>1.13; 0.83–1.53</td>
<td>0.443</td>
<td>1.2; 0.98–1.47</td>
<td>0.076</td>
</tr>
<tr>
<td>Epicardial ablation</td>
<td>1.86; 0.76–4.53</td>
<td>0.172</td>
<td></td>
<td></td>
</tr>
<tr>
<td>β-Blocker</td>
<td>2.04; 0.63–6.62</td>
<td>0.236</td>
<td>1.02; 0.24–4.3</td>
<td>0.975</td>
</tr>
<tr>
<td>AAM</td>
<td>0.48; 0.22–1.07</td>
<td>0.072</td>
<td>1.71; 0.94–3.1</td>
<td>0.079</td>
</tr>
</tbody>
</table>

Catheter Ablation in DCM-VT
Improved Success with Scar Homogenization (?)

The Difficult VT Ablation
Can we improve outcomes?

- Deep (Septal) Circuits
  - Hemodynamic Support
  - Bipolar RF
  - EtOH Ablation
- Epicardial Ablation
- Neuraxial Modulation

The Difficult VT Ablation
Can we improve outcomes?

Mostly Intramural Scar:
What do you do?

• Deep (Septal) Circuits
  • Hemodynamic Support
  • Bipolar RF
  • EtOH Ablation
• Epicardial Ablation
• Neuraxial Modulation
Bipolar Ablation

Clinical Case Example

Sequential Unipolar  Bipolar Ablation

The Difficult VT Ablation
Can we improve outcomes?

- Deep (Septal) Circuits
  - Hemodynamic Support
  - Bipolar RF
  - EtOH Ablation
- Epicardial Ablation
- Neuraxial Modulation
The Difficult VT Ablation
Can we improve outcomes?

- Deep (Septal) Circuits
  - Hemodynamic Support
  - Bipolar RF
  - EtOH Ablation
- Epicardial Ablation
- Neuraxial Modulation
The Difficult VT Ablation
Can we improve outcomes?

- Deep (Septal) Circuits
  - Hemodynamic Support
  - Bipolar RF
  - EtOH Ablation
- Epicardial Ablation
- Neuraxial Modulation

Modified from slide from: E Sosa, M Scanavacca, A d’Avila
ARVC-Related

High Success of VT Ablation

• 17 Patients
• Mean f/u: 49 ± 21 mo
• Success rate: 88%

Reddy & Wilber, Manuscript in Preparation

The Difficult VT Ablation
Can we improve outcomes?

- Deep (Septal) Circuits
  - Hemodynamic Support
  - Bipolar RF
  - EtOH Ablation
- Epicardial Ablation
- Neuraxial Modulation
  - Renal Denervation
  - Stellate Ganglionectomy
RSDN for Ventricular Arrhythmias
On-Going Clinical Trials

REnal SympatheCtiC Denervation to sUpprEss Tachyarrhythmias (RESCUE)

This study is currently recruiting participants. (see Contacts and Locations)
Verified June 2016 by Icahn School of Medicine at Mount Sinai
Sponsor:
Vivek Reddy
Information provided by (Responsible Party):
Vivek Reddy, Icahn School of Medicine at Mount Sinai

Renal Denervation in Patients After Acute Coronary Syndrome (ACR-ART)

This study is currently recruiting participants. (see Contacts and Locations)
Verified September 2015 by Meshalkin Research Institute of Pathology of Circulation
Sponsor:
Meshalkin Research Institute of Pathology of Circulation
Information provided by (Responsible Party):
Meshalkin Research Institute of Pathology of Circulation

Renal Nerve Stimulation and Renal Denervation in Patients With Sympathetic Ventricular Arrhythmias (Ressess VT)

This study is currently recruiting participants. (see Contacts and Locations)
Verified August 2016 by Diagram B.V.
Sponsor:
Diagram B.V.
Information provided by (Responsible Party):
Diagram B.V.

RESCUE-VT

2° Prevention
1° Prevention + Inducible VT

ICD Implantation

Renal Angiogram

Placebo

RSDN

Follow-Up ICD Therapy

Diagram B.V.
The Difficult VT Ablation
Can we improve outcomes?

- Deep (Septal) Circuits
  - Hemodynamic Support
  - Bipolar RF
  - EtOH Ablation
- Epicardial Ablation
- Neuraxial Modulation
  - Renal Denervation
  - Stellate Ganglionectomy

Stellate Ganglionectomy Case Series

ICD Shocks: Left vs Bilateral CSD

Success & Mortality After VT Ablation

Effect of Acute Inducibility: Mortality

- 528 scar-VT patients treated with ablation
- Results of programmed stimulation:
  - Class A (Non-inducibility of any VT) → 77%
  - Class B (Inducibility of “non-clinical” VT) → 12.4%
  - Class C (Inducibility of “clinical” VT) → 10.6%

Predictors of Transplant/Mortality

<table>
<thead>
<tr>
<th>Effect</th>
<th>Transplant/Mortality</th>
<th>Hazard Ratio (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICD</td>
<td>-</td>
<td>0.685 (0.376 - 1.240)</td>
<td>0.214</td>
</tr>
<tr>
<td>EF Pre-Ablation (+5%)</td>
<td>-</td>
<td>0.858 (0.796 - 0.925)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Beta Blocker</td>
<td>-</td>
<td>0.878 (0.620 - 1.244)</td>
<td>0.464</td>
</tr>
<tr>
<td>Ischemic Cardiomyopathy</td>
<td>-</td>
<td>0.999 (0.753 - 1.325)</td>
<td>0.994</td>
</tr>
<tr>
<td>Atrial Fibrillation</td>
<td>-</td>
<td>1.028 (0.782 - 1.352)</td>
<td>0.843</td>
</tr>
<tr>
<td>Amiodarone</td>
<td>-</td>
<td>1.057 (0.767 - 1.456)</td>
<td>0.737</td>
</tr>
<tr>
<td>≥ 2 AAD</td>
<td>-</td>
<td>1.062 (0.774 - 1.458)</td>
<td>0.708</td>
</tr>
<tr>
<td>Age (+6y)</td>
<td>-</td>
<td>1.066 (1.001 - 1.136)</td>
<td>0.048</td>
</tr>
<tr>
<td>ICD Shocks</td>
<td>-</td>
<td>1.104 (0.782 - 1.559)</td>
<td>0.573</td>
</tr>
<tr>
<td>Prior VT Ablations (+1)</td>
<td>-</td>
<td>1.112 (0.971 - 1.273)</td>
<td>0.126</td>
</tr>
<tr>
<td>Female</td>
<td>-</td>
<td>1.187 (0.806 - 1.747)</td>
<td>0.386</td>
</tr>
<tr>
<td>CRT</td>
<td>-</td>
<td>1.204 (0.913 - 1.587)</td>
<td>0.188</td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
<td>-</td>
<td>1.369 (1.036 - 1.809)</td>
<td>0.027</td>
</tr>
<tr>
<td>Chronic Kidney Disease</td>
<td>-</td>
<td>1.438 (1.094 - 1.891)</td>
<td>0.009</td>
</tr>
<tr>
<td>Electrical Storm</td>
<td>-</td>
<td>1.499 (1.135 - 1.980)</td>
<td>0.004</td>
</tr>
<tr>
<td>NYHA: II v. I</td>
<td>-</td>
<td>1.506 (0.914 - 2.479)</td>
<td>0.108</td>
</tr>
<tr>
<td>NYHA: III v. II</td>
<td>-</td>
<td>2.308 (1.403 - 3.798)</td>
<td>0.001</td>
</tr>
<tr>
<td>NYHA: IV v. I</td>
<td>-</td>
<td>3.681 (2.004 - 6.760)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Procedural Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ablation: Epi v. Endo</td>
<td>-</td>
<td>0.767 (0.379 - 1.552)</td>
<td>0.461</td>
</tr>
<tr>
<td>Ablation: Endo + Epi v. Endo</td>
<td>-</td>
<td>0.959 (0.665 - 1.385)</td>
<td>0.825</td>
</tr>
<tr>
<td>Procedure Time (+15m)</td>
<td>-</td>
<td>0.996 (0.975 - 1.017)</td>
<td>0.697</td>
</tr>
<tr>
<td>VTs Induced: 1 v. 0</td>
<td>-</td>
<td>1.285 (0.703 - 2.350)</td>
<td>0.416</td>
</tr>
<tr>
<td>VTs Induced: 2 v. 0</td>
<td>-</td>
<td>1.625 (0.900 - 2.935)</td>
<td>0.107</td>
</tr>
<tr>
<td>VTs Induced: 3 v. 0</td>
<td>-</td>
<td>1.522 (0.851 - 2.721)</td>
<td>0.157</td>
</tr>
<tr>
<td>Procedural Complications</td>
<td>-</td>
<td>1.298 (0.836 - 2.015)</td>
<td>0.246</td>
</tr>
<tr>
<td>Hemodynamic Support Device</td>
<td>-</td>
<td>2.128 (1.415 - 3.199)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Outcomes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute: Not Tested v. Nil</td>
<td>-</td>
<td>1.972 (1.248 - 3.116)</td>
<td>0.004</td>
</tr>
<tr>
<td>Acute: Partial/Failure v. Nil</td>
<td>-</td>
<td>1.994 (1.480 - 2.687)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>VT Recurrence</td>
<td>-</td>
<td>6.901 (5.282 - 9.017)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Transplant/Mortality After VT Ablation

Outcome: Relationship to Functional Class

Outline

• Scar-Related VT Ablation
• Outflow-Tract VT/PVCs
• Ventricular Fibrillation
Outflow-Tract VT

- Structurally-normal heart
- RVOT- or LVOT-VT
- ECG:
  - Typically LBBB (or RBBB)
  - Positive QRS in II / III / aVF
  - QRS transition V3/V4
    - Early transition → LVOT
    - Can be RBBB
- Not life-threatening
  - [rare exceptions]
45 yo Fireman with OTVT → ICD

ICD Interrogation
RVOT VT Ablation
What about PVCs?
Canine Model

Bigeminal PVC Pacing vs Control

• **13% baseline PVC burden**: 100% Sens / 85% Specificity to predict an absolute LVEF increase of 5% after catheter ablation

• 20 patients with Class I ICD indication no longer eligible at 6 months post-ablation.
CRT Non-Responders
Effect of PVC Ablation

- 65 CRT Non-Responders with >10,000 PVCs/24h undergoing ablation
- Age 66.6, 78% male, QRS duration = 155 ± 18 msec
- Acute and 12-mo success of ablation: 91% and 88%
- Improvements in LVEF (26.2 → 32.7%, p 0.001)
  - LVESD, LVEDD, LVESV, LVEDV, NYHA (3.0 to 2.0, p 0.001)

Lakkireddy et al, JACC 60:1531 (2012)
Predictors of PVC-Cardiomyopathy

Interpolated PVCs

- Interpolated PVCs
  - Higher risk for Cardiomyopathy

- Symptoms
  - Asymptomatic: HR = 13
  - Long duration (>60mo): HR=20

- QRS Width
  - QRS >150ms best predictive
  - Sens = 80% / Spec = 52%

Olgun et al, *Heart Rhythm* 8:1046 (2011)
• Scar-Related VT Ablation
• Outflow-Tract VT/PVCs
• Ventricular Fibrillation
  – Focal Trigger Ablation
  – Substrate Modification (Brugada)
Case: 16 yo, Normal LVEF, Syncope
Exercise Treadmill Testing
Ventricular Fibrillation

Focal Triggers

RVOT muscle 16%

Purkinje 84%

Both foci in 4 pts

Initiation of VF by “Purkinje beats”

[Diagram showing electrocardiogram with annotations]

LV dist

LV prox

Courtesy: Michel Haissaguerre
Case: Ablation
VF Triggers in Other Disease States

Channelopathy & Post-MI

VF Substrate Mapping in Brugada Syndrome
Normal and Abnormal Epicardial Electrograms

VF Substrate Mapping in Brugada Syndrome
Effect of IV Flecainide

Pre-Flecainide

Post-Flecainide

Brugada Syndrome: VF Substrate Ablation

ECG Pattern During Follow-Up

Pre-Ablation

Follow-Up

Baseline

Post-Flecainide

J.Brugada, C.Pappone, A.Berruezo et al, Circ Arrhythm, 8:1373 (2015)
Final Thoughts

• **Scar-Related VT:**
  - Ablation is safe!
  - Ablation success is moderate in DCM
  - ARVC-VT Ablation: Excellent Outcome

• **Outflow-Tract VT**
  - Recognize it! → ICDs are not indicated
  - PVCs – When to intervene?
    - Symptoms
    - Ventricular Dysfunction / Dilatation
    - High burden??

• **Ventricular Fibrillation**
  - PVC Triggers
  - Brugada Syndrome: Substrate Ablation
Mount Sinai School of Medicine