Ablation of Scar-Related Ventricular Tachycardia: Approaches for Stable and Unstable Tachycardias

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Disclosures: None

Scar-Related Sustained Monomorphous VT

- Prior myocardial infarction
- Nonischemic cardiomyopathies
  - Arrhythmogenic RV Dysplasia
  - Sarcoidosis
  - Idiopathic
  - Familial
- Surgical Repairs
  - Tetralogy of Fallot / VSD repairs
  - Valvular heart disease

Nonischemic cardiomyopathy - ventricular scar identified by MRI is associated with ventricular tachycardia.
Nazarian et al. Circulation 2005;112:2821

Late after myocardial infarction: extent of heterogeneous infarct border predicts mortality and VT susceptibility.
Kwong et al Circulation 2006; Schmidt et al Circulation 2007

Need for Arrhythmia Management After ICD placement

**Secondary Prevention ICD**
- shocks for VT: 40 – 60%
- >3 shocks in 24 hrs: 20%
- Need for AADs – 20%

**Primary Prevention ICD**
- shocks for VT - 5% year
- Inappropriate shocks - 2.5%/yr
- Need for AA drugs – 14%

**Symptomatic VT After ICD**
- Antiarrhythmic Drugs
- Catheter Ablation

AVID VT storm, Exner et al Circ 2001;103:201
AVID Quality of life, Schron Circ 2002;105:589
Considerations for VT ablation

- Tolerance for procedure
  - Potential for hemodynamic instability
    - Volume status
    - Potential ischemia
  - Sedation risks
  - Potential for incessant VT

- Likely ventricle of origin
  - Access to the ventricle
    - Mechanical valves
    - Peripheral vascular disease
  - LV thrombus

RF Catheter Ablation Guided by Electroanatomic Mapping for Recurrent VT After Myocardial Infarction
Stevenson WG, et al Circulation 2008; 118: 2773

Characteristics of induced VTs in 231 patients: median of 3 VTs/patient

- Frequent VT failing therapy - 11 episodes in prior 6 mo
- Median LVEF 0.25

53% free of any VT* at 6 months
(* or incessant VT for pts with prior incessant VT)

Heart Rhythm 2009 (June); 6: 886-933
EHRA/HRA Expert Consensus on Catheter Ablation of VT - 2009

Definitions

Clinical VT: VT that has occurred spontaneously based on analysis of 12-lead ECG and rate

Presumptive clinical VT: is similar to a spontaneous VT based on rate and ECG or ICD interrogation data, but 12-lead ECG data is not available

Undocumented VT morphology: induced monomorphic VT that has not been previously observed to occur spontaneously

Avoid the term “nonclinical VT”

Scar – related Reentry

Potential for Multiple reentry circuits
- Endocardial
- Intramural
- Epicardial

Catheter ablation for scar-related reentry: Challenges
- Areas of scar are often large
- Reentry circuits can be large
- Ablation lesions are relatively small

Requires localization of critical reentry circuit sites
VT Due to Scar-Related Reentry: Mapping to Guide Ablation

- A variety of strategies are reasonable.
- In general, it is desirable to first induce VT
  - To confirm the diagnosis
  - to evaluate the possibility of bundle branch reentry
  - to establish inducibility for interpretation as an endpoint
  - to record the 12-lead ECG morphology of VT.

Substrate Mapping

- **Substrate mapping** is the characterization of areas likely to support reentry based on anatomy and electrophysiological characteristics that can be determined during stable sinus or paced rhythm.
- This approach can facilitate ablation of
  - Multiple VTs
  - pleomorphic VTs
  - VTs hemodynamic unstable VTs
  - VTs that are not reliably inducible.
- For tolerated VT substrate mapping is commonly used to limit activation sequence mapping or entrainment mapping to a region of interest.

- **Voltage map – Inferior wall MI**
  - Low amplitude region correlates well the infarct region in animal models
    - 95% of normal LV electrograms > 1.55 mV
      - (bipolar 4 mm tip to 2 mm ring electrode, filtered at 10 to 400 Hz)
      - Marchlinski et al Circ 2000;101:1288; Reddy JACC 2003;41:2228
Substrate Guided Approach: Identifying exits and channels in scars

Identify Exits in the scar border - pace mapping / QRS

and / or

Identify Channels / Isthmuses
- Electrically unexcitable scar
  Soejima 2002
- Pace-mapping for slow conduction and QRS morphology
- Isolated potentials (SR or V pacing)
  Arenal 2004, Nakagawa 2004 abst
- EG amplitude - Arenal 2004

* The different criteria for identifying exits and placing RF lesions have been described in single center studies and have not been directly compared. EHRA/HRS Scientific Statement

Manipulation of Voltage Color Range for Infarct Characterization

Two types of low voltage regions:

Electrically unexcitable scar (EUS)
- dense fibrosis high pacing threshold
- potential reentry circuit border

Low voltage excitable regions:
- fibrosis + myocytes
- potential reentry circuit channels

Electrically unexcitable scar (EUS)
Pacing threshold > 10 mA
Amplitude usually < 0.5 mv

Soejima et al Circ 2002;106:1678
Case 1: Stable VT

- Elderly male with CAD
- Recurrent VT late after MI
- Failed prior endocardial ablation attempt

VT Due to Scar-Related Reentry: Hemodynamically Tolerated VT

- When there is a clear clinical VT that is tolerated (including incessant VT):
  - a combination of activation sequence mapping and entrainment mapping to identify a critical isthmus for ablation are reasonable.
  - Substrate guided ablation can also be used to help direct ablation.
  - Once VT is terminated by ablation, additional lesions may be placed creating ablation lines that meet valve annuli or dense unexcitable scar that may form borders of the reentry path.

Activation Sequence Mapping

- Activation sequence mapping is a valuable strategy that can be used alone or in conjunction with substrate mapping entrainment mapping, and/or pace mapping.
- For stable VT, complete activation sequences may be defined and used with entrainment mapping to guide ablation.
- More commonly, limited activation assessment, noting areas of pre-systolic activity and isolated potentials, is performed, and this information is integrated with entrainment mapping data to guide ablation.
Mapping

- **Entrainment mapping** is useful for identifying reentry circuit sites and recognizing bystander sites in stable VT. Has been used in a limited way in unstable VT.

EHRA/HRS Expert Consensus on Catheter Ablation of Ventricular Arrhythmias 2009

Pacing from the mapping catheter to identify reentry circuit sites: distinguishing “local” signals from “far-field” signals

Use of the PPI assumes that the electrogram selected for measurement indicates activation at the pacing site.

Far-field signal visible and separate from pacing stimulus

Local signal obscured during pacing with capture

Tung et al JACC 2003;42:110
Broad Loop - fusion is overt versus narrow isthmus (channel) fusion is concealed

Entrainment with Fusion

Entrainment: Concealed Fusion

Tachycardia

Pacing at LV site

RF fails to interrupt VT

RF on at exit site

RF off

VT - 1

VT - 1

VT-3 Subtle change in QRS
Termination without a propagated response:
- Mechanical
- Local capture

Termination without global capture: a marker of reentry circuit isthmus

Targeting a channel within the low voltage region
- Inside the border zone (< 1 mv)
  - Far-field and local signals
  - Fractionated SR Egs
  - SR very late potentials

Voltage Map: Isthmus / Channel characteristics
- Inside the border zone (< 1 mv)

Pace-map: long S-QRS
- matches VT if the paced wavefront propagates out the exit for that VT
- does not match VT if the paced wavefront does not follow the reentry path

Entrainment – concealed fusion

Pace-mapping: QRS match indicates the likely exit - but QRS may not match at other sites in the reentry circuit

Pace-mapping - No match

Entrainment

Entrainment – concealed fusion

Far-field signal

Another VT inducible

Pace-map at exit for VT – 2
QRS matches VT

RF on carto 107
Acute Endpoints of Ablation

- When clinical or presumed clinical VTs can be induced, the minimum endpoint of ablation should be to eliminate the induction of that VT. (PES with up to 3 extrastimuli, from 2 sites to shortest coupling intervals of 180–200 ms or refractoriness.

- Incessant VT - restoration of stable sinus rhythm is a reasonable clinical endpoint

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Acute Endpoints of Ablation

- Three general endpoints have been evaluated:
  - non-inducibility of clinical VT
  - modification of induced VT cycle length (elimination of all VTs with cycle lengths ≥/≤ spontaneously documented or targeted VT)
  - non-inducibility of any VT (excluding ventricular flutter and fibrillation).

Case 2: Recurrent VT late after anterior wall MI

- 57 year old male
- CABG 7 yrs prior, multiple PCIs since
- Recurrent VT 3 yrs prior
- LVEF 0.15
- Failed amiodarone, mexiletine

Step 1: Initiation of VT-1
- assess QRS morphology
- evaluate for bundle branch reentry
Pacing accelerates VT-1 to VT-2

Cardioversion of VT-2

Approaches to Selecting Ablation Targets for Unstable VTs

- Substrate mapping
- Multielectrode array mapping:
  - Activation map single beats of VT
- Hemodynamic support during VT
  - IABP
  - Percutaneous hemodynamic support

Identifying exits from Unipolar Recordings: Non-contact mapping

Endocardial exits are indicated by regions with presystolic activity and QS electrograms

Non-contact mapping to guide catheter ablation of untolerated VT
Della Bella, et al   Eur Heart J 2002;23:742

- 17 patients: 11 with prior MI, 3 ARVD, 3 IDCM
- 27 VTs (mean CL 320 ms, 230-450 ms)
  - mapped for 15-20 s, then terminated
  - Off line analysis of isopotential activation
  - RF across the diastolic pathway or around the exit
- Endocardial exit defined in 93% of VTs
- Diastolic pathway identified in 70% of VTs
- 16/25 VTs targeted (64%) were successfully ablated in 10/17 patients (59%)
- Follow-up of 15+/-5 months
  - Recurrent VT in 2 of 10 with acutely successful ablation
  - Recurrent VT in 5 of 7 with acute ablation failure

Schilling et al  Circulation 1999

Combining Contact Voltage Maps and Activation Data

**Different VTs = different exits along the scar border**
Contact voltage map that shows multiple VT exits (E) defined by noncontact mapping

EHRA/HRS Expert Consensus on Catheter Ablation of VT - 2009

**VT Due to Scar-Related Reentry: Unstable VTs / Multiple VTs**

- Many centers start with substrate mapping during stable sinus rhythm.
  - Brief episodes of VT can be induced to assess the potential location of the reentry circuit, with prompt termination of VT if required to help select the ablation region.
  - Alternatively, ablation can be performed guided by substrate characteristics.
- These different approaches have not been directly compared.

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Step 2: LV Voltage Map During Sinus Rhythm
Site 24 pace-map

Site 24

C 65 – electrically unexcitable scar (EUS)

After RF 9 – dissociated LP at c 178
After RF 9: site 179 – no capture, dissociated potential

Programmed stimulation after RF 10: VT-3

Final RF lesion set

Acute Endpoints of Ablation

Some patients undergoing VT ablation have significant hemodynamic compromise and substantial ischaemic burden often aggravated by prolonged periods of tachycardia.

Post-procedure stimulation to assess VT inducibility should be avoided if in the judgement of the physician, it places the patient at risk of cardiopulmonary deterioration.

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What is the mechanism of VT?

Purkinje System Involvement in Scar-Related VTs

- Purkinje Fibers can participate in scar-related reentry
- Bundle branch reentry
- Interfascicular reentry
- Automaticity


Impact of Catheter Ablation on Recurrent VT

Stevenson et al Multicenter Thermocool VT Ablation Trial. Circulation 2008;118:2773

N = 142

VT Episodes pre-ablation: median 11.5
VT Episodes pre-ablation: median 0
P < 0.0001

Isthmus 1: Between Free Wall Scar and TA
present in all pts; involved in 11/15 VTs
Isthmus 2: Free wall scar – PV:
uncommon, absent with transannular patch
Isthmus 3: Septal patch - PV
Isthmus 4: Septal patch - TA:
Catheter Ablation for the Treatment of Electrical Storm in Patients With Implantable Cardioverter-Defibrillators

95 patients
LVEF 0.36 ± 0.1
CAD 76%
Failed amiodarone 94%

Ablation for Scar-Related VT

- Reduces ICD therapies in > 70% of patients
  - Mortality 3%
    - Most due to uncontrollable VT when the procedure fails
  - Stroke 0 - 2.7%
  - Vascular complications: 10%
    - Femoral hematomas, pseudoaneurysms
- Live-saving for incessant VT and VT storm

Why do we fail?
Anatomic reasons

Deep intramural reentry circuits

Failed Endocardial RF ablation:
Options

- Epicardial mapping and ablation
  - Required in approximately 12% of patients
  - Requires surgical window for pts with prior CABG
- Transcoronary ethanol ablation
  - Used in 1-2% of patients
  - Requires an identifiable coronary target
  - Risk of large areas of damage
- Surgical Ablation

Sosa et al. JACC 2000;35:1442; Brugada et al. JACC 2003;41:2036
Sosa et al. JACC 2004, Circulation 2003, Casario et al Heart Rhythm 2006;3:1
Survival after VT ablation - Brigham and Women’s Hospital

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Survival rates for patients with different conditions:
- No Structural Heart Disease
- Non Ischemic CMP
- Ischemic CMP

p < 0.0001

Thank You