Mapping and Ablation of VT with Prior Myocardial Infarction

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VANDERBILT HEART

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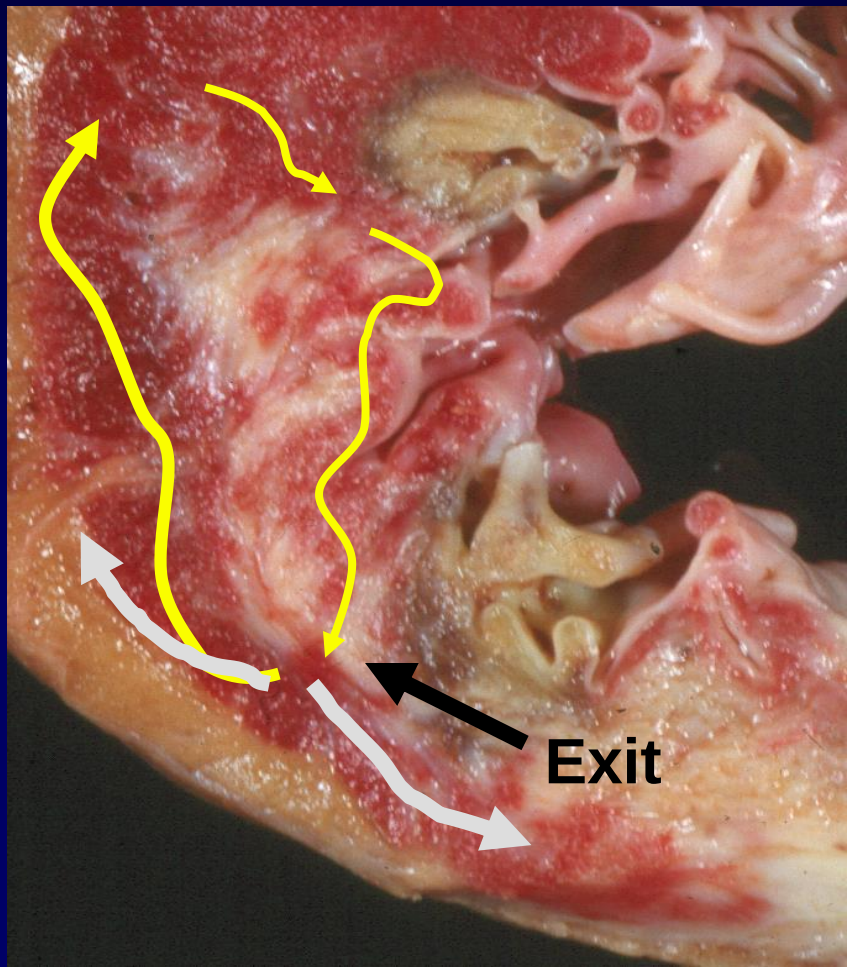
- Disclosures
  - Honoria
    - Abbott
    - Biotronik
    - Boston Scientific
    - Johnson and Johnson
  - Intellectual Property
    - Patent for irrigated needle ablation consigned to Brigham Hospital
  - Consulting
    - Novartis

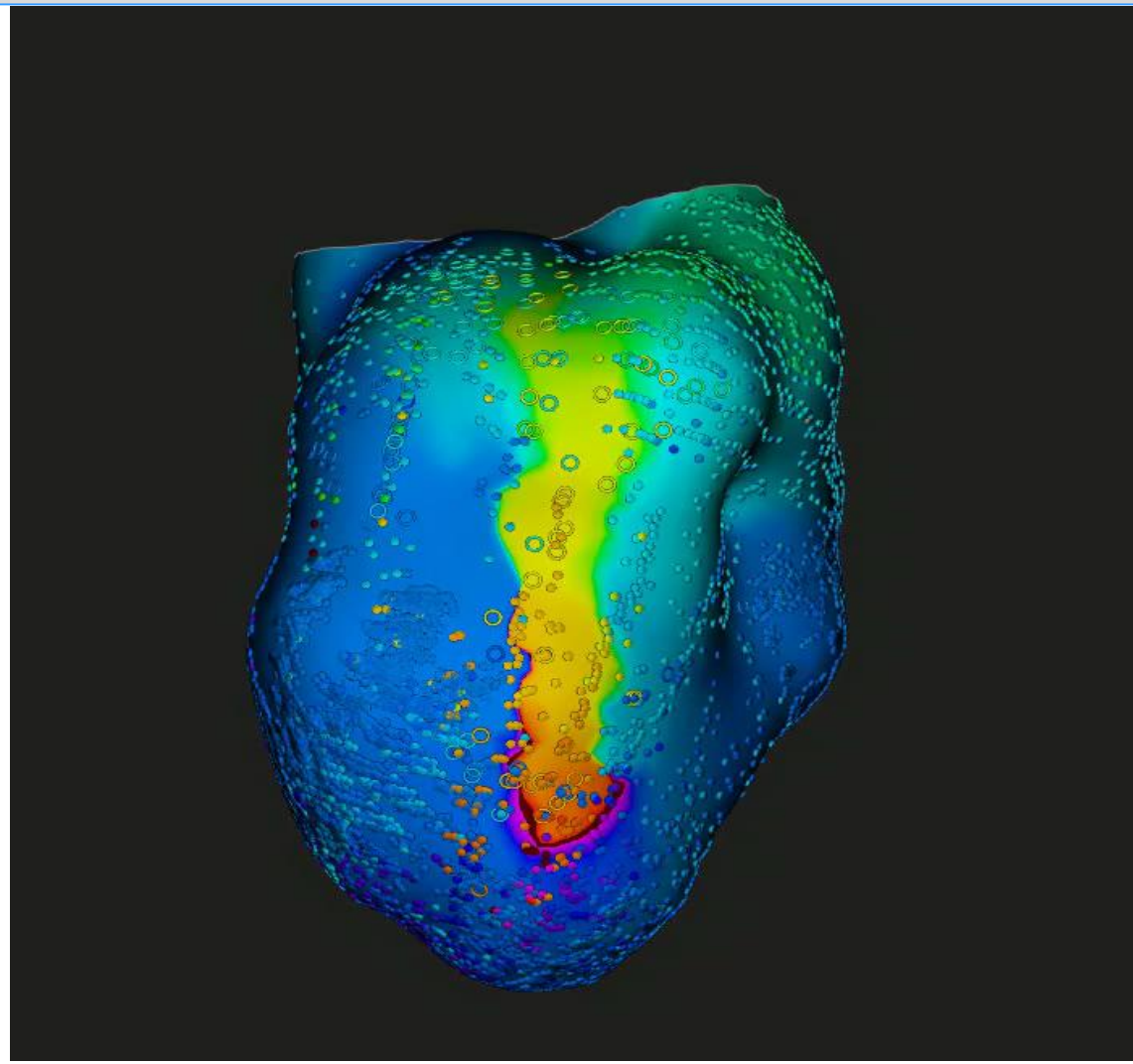
VT post infarction

- Reentry involving regions of ventricular scar is the most common cause



- Uncommon mechanisms
  - Bundle branch reentry
  - Focal Automaticity

Monomorphic VT can also be due to reentry circuits that are defined by functional conduction block



High resolution mapping and entrainment of reentry in 6 – 8 wk old swine infarct model

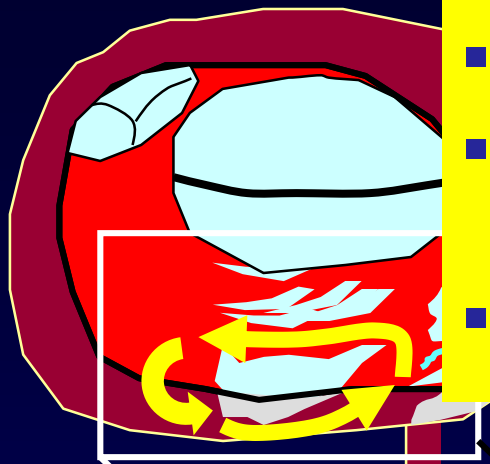
Stable reentry circuit isthmuses can be defined by defined by slow propagation transverse to fiber orientation and wavefront collision.

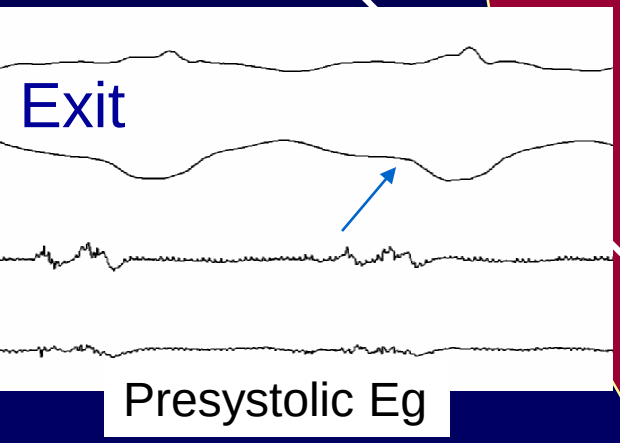
Slow conduction occurs at areas of high wavefront curvature at entrance and exit regions

Anter et al Circulation 2016

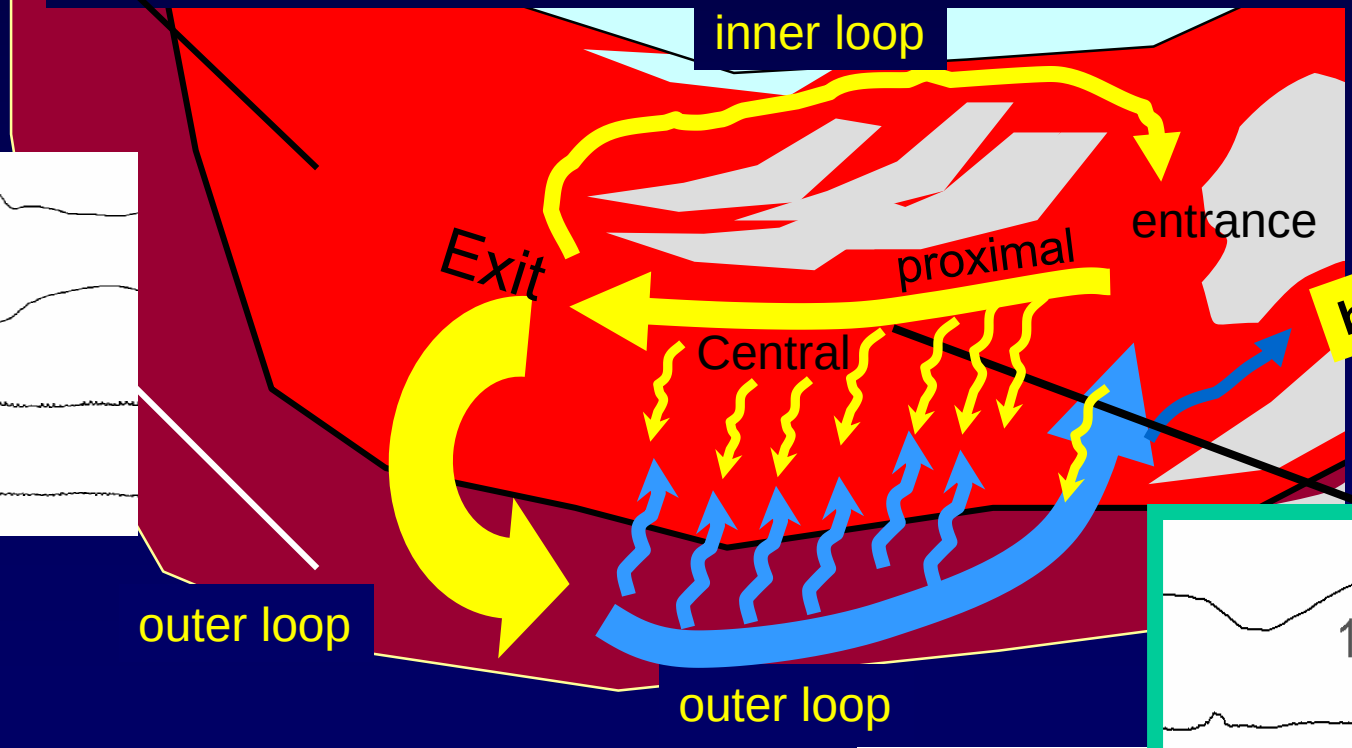
Multi-loop reentry:

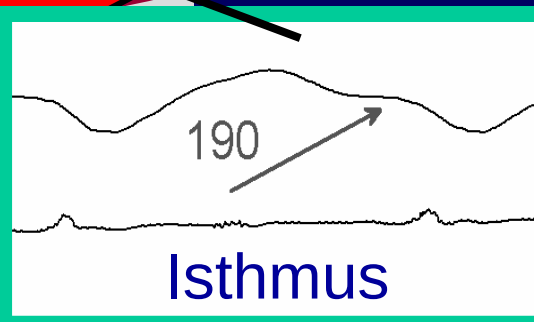
- QRS morphology reflects the reentry circuit exit
- Presystolic activation may indicate a channel, but can also originate from a bystander region
- Channels can be defined by fixed or functional block





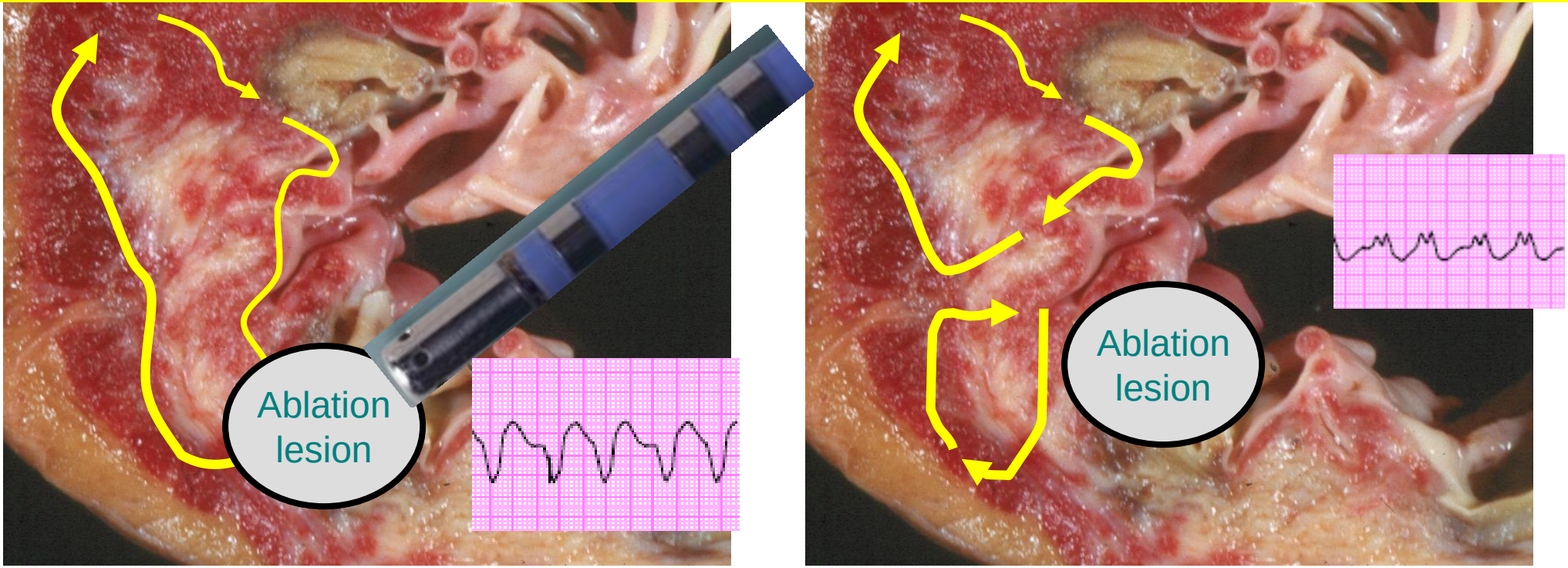
Presystolic Eg





Diastolic Eg

Catheter ablation of scar-related VT can be challenging



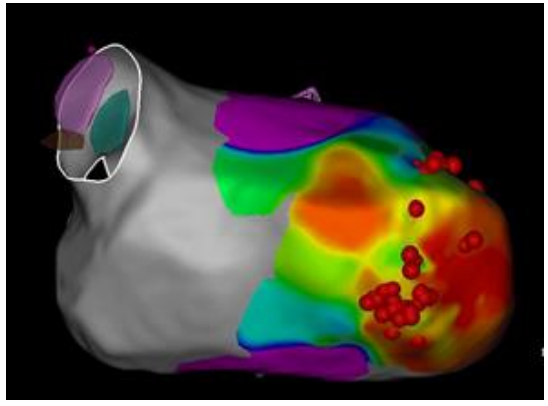
- If the substrate for one VT is present, multiple VTs are often inducible
- Infarcts associated with VT are often large
- Reentry substrate favors the subendocardium, but can be 3-dimensional extending to intramural and subepicardial areas

Approaches to Catheter Ablation of Post MI VT

Target Isthmuses /channels of specific VTs

↓

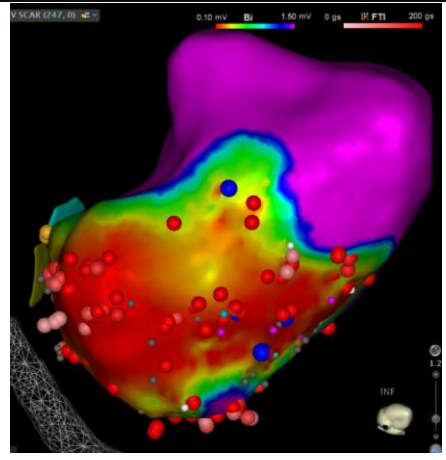
Endpoint
Absence of inducible VT



Target all potential channels during sinus or paced rhythm

↓

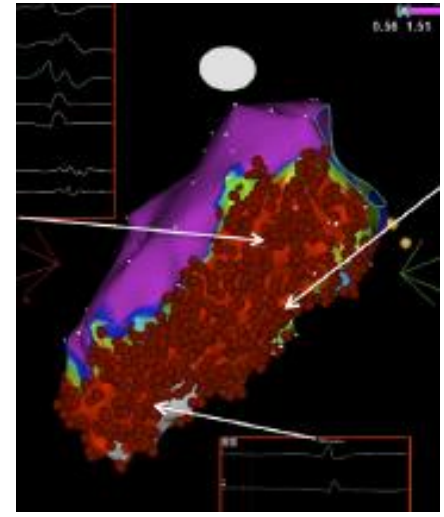
Endpoint
- Absence of inducible VT and LP/LAVA
- core isolation



Scar homogenization

↓

Endpoint
Anatomic coverage of the low voltage area



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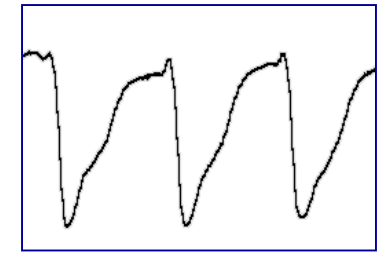
Targeting the Specific VT Isthmus

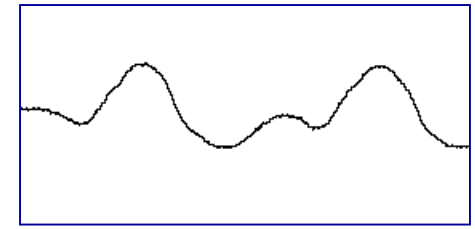
- Incessant VT
- Known clinical VT
- Failed prior substrate ablation
- VT substrate in a high risk area
  - AV conduction at risk in basal septum
  - Epicardial
    - Adjacent to phrenic nerve
    - Adjacent to coronary artery

Monomorphic VT: QRS configuration suggests the exit

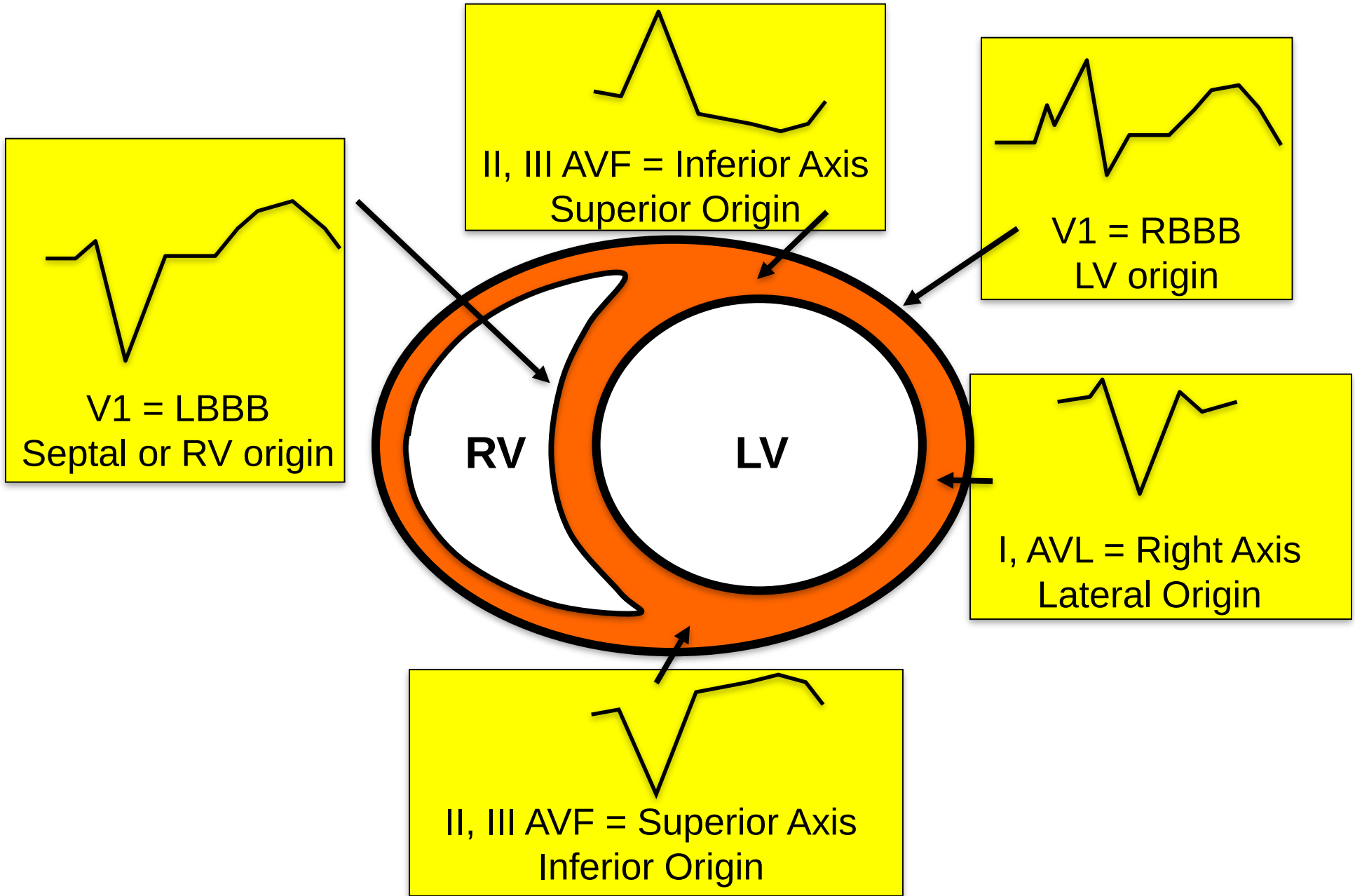
- **left bundle branch block** configuration in V1
  - LV septal exit
  - RV origin (<10%)
    - bundle branch reentry (5%)
    - RV scar (5% of ischemic heart disease VT patients)



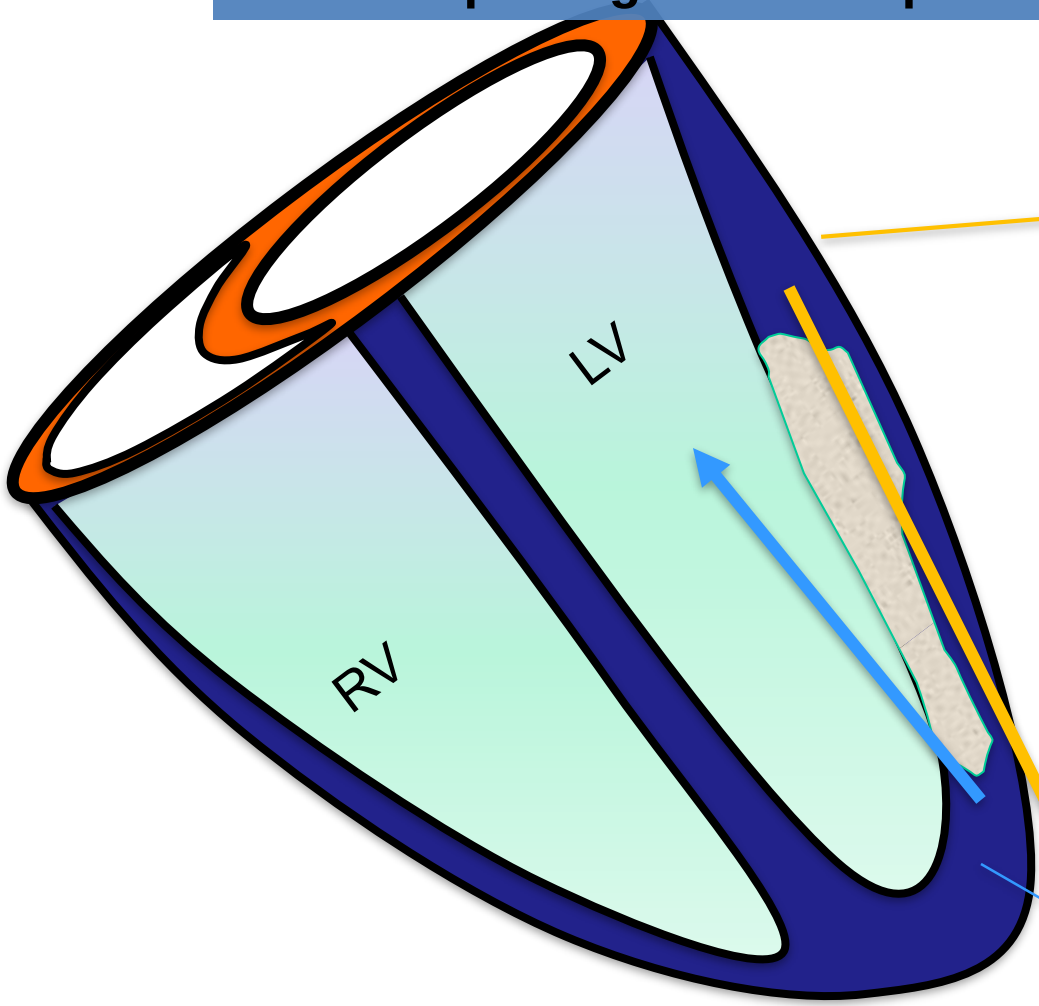
- **Right bundle branch block** configuration in V1
  - Left ventricular origin



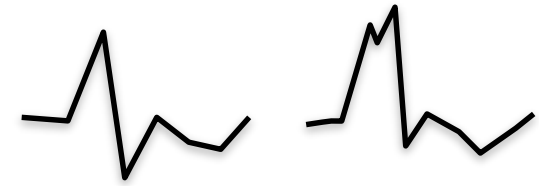
ECG morphologies and VT exit / origin

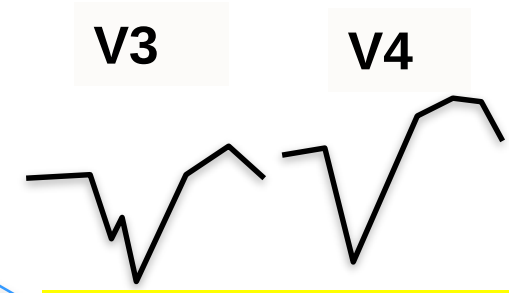


ECG morphologies in mid precordial leads and VT exit / origin



Basal origin suggested by dominant R waves in V3,4





Apical origin suggested by dominant S waves in V3,4

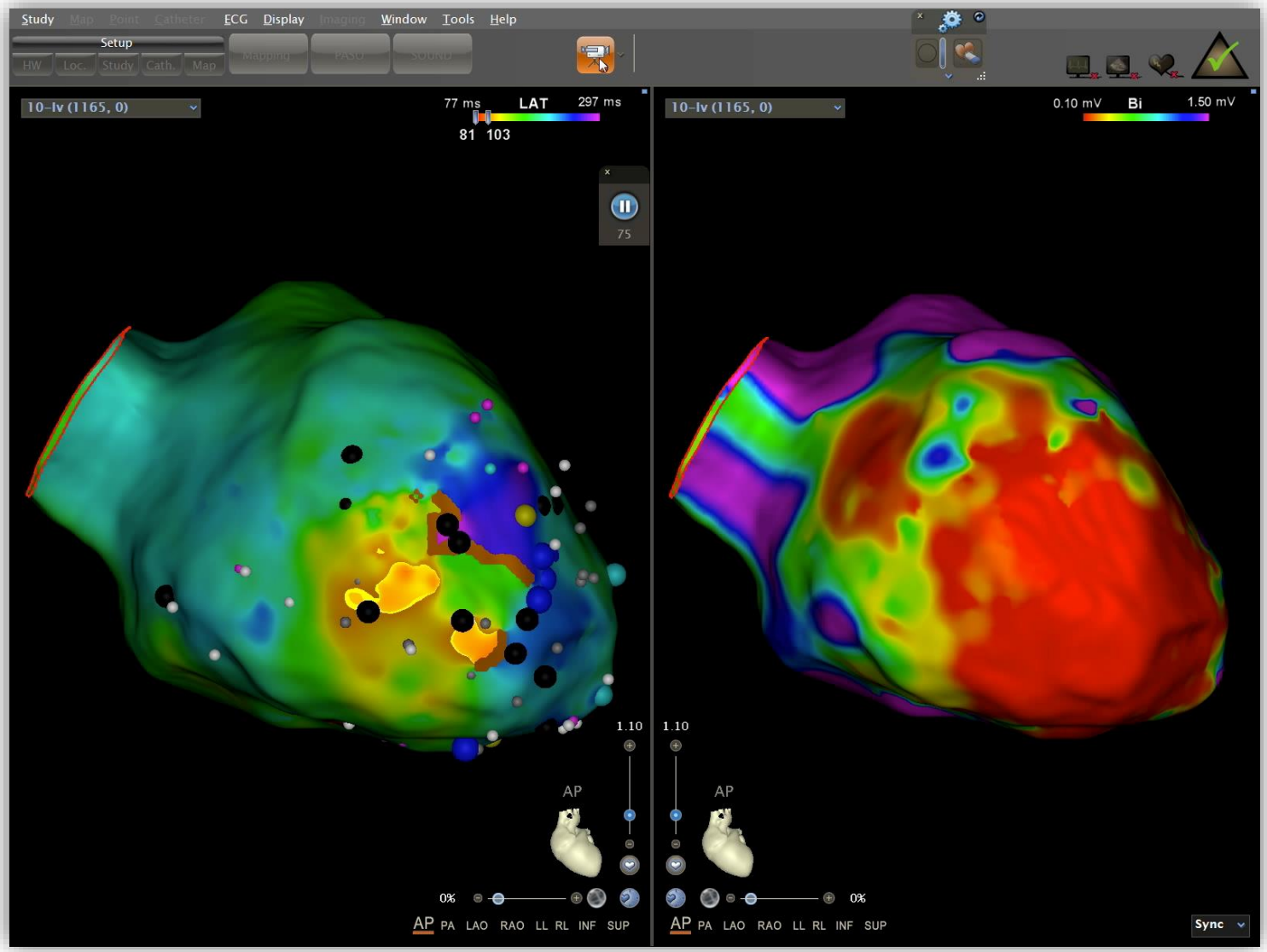
V1

V3

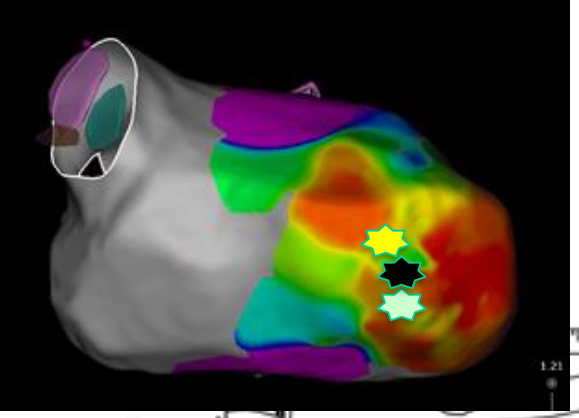
V4

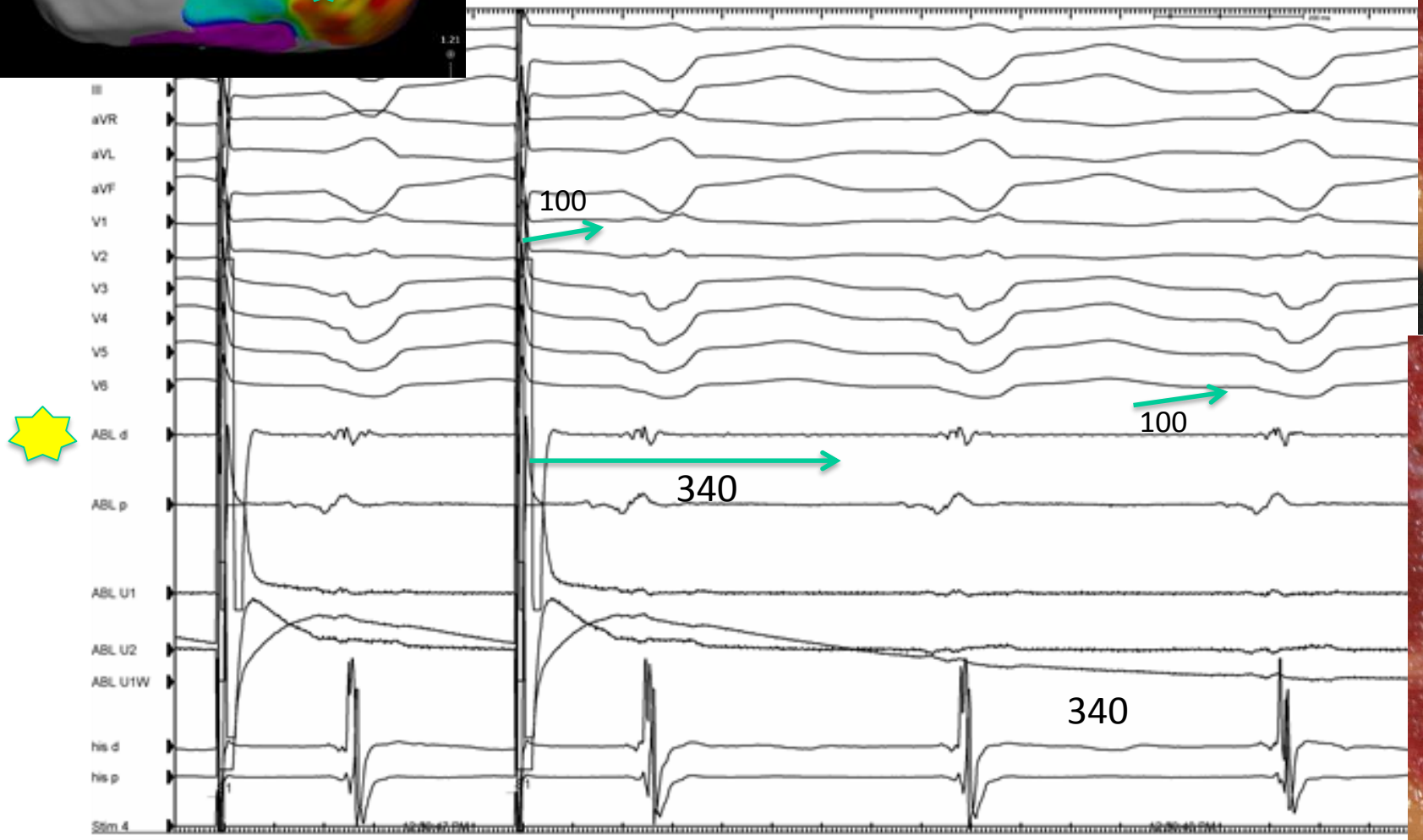
Propagation during VT from multielectrode mapping

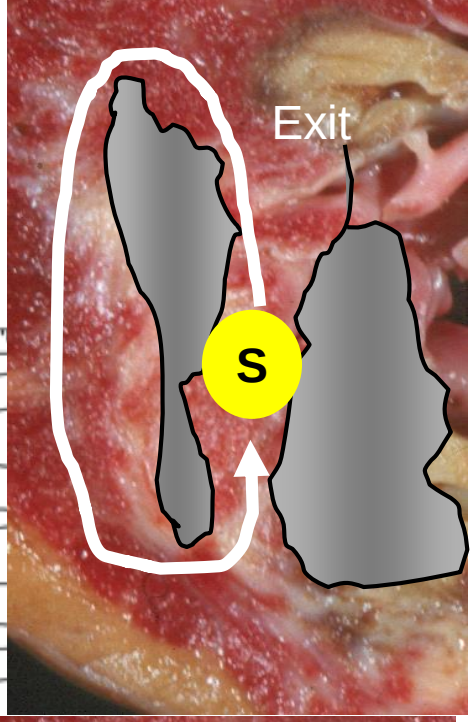
Voltage Map

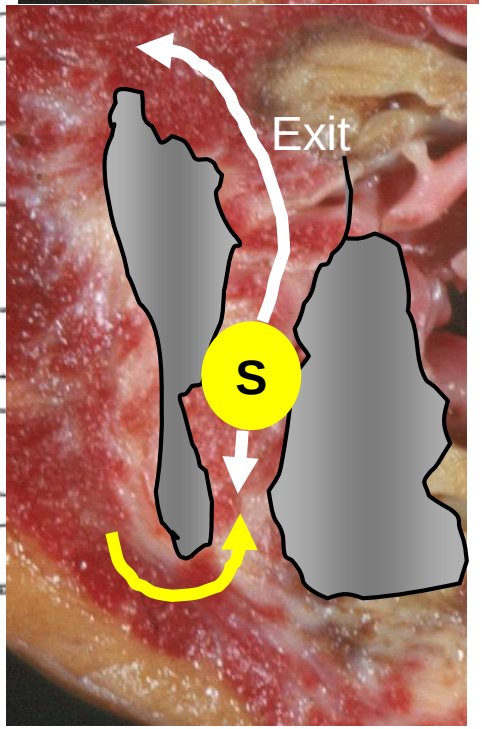


Entrainment: isthmus site
- concealed fusion
- S-QRS = Eg – QRS
PPI = VTCL

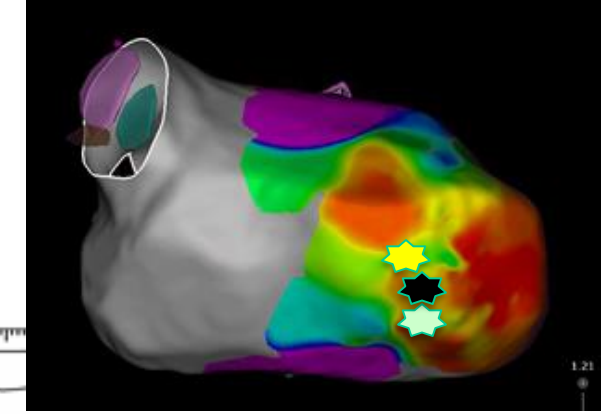






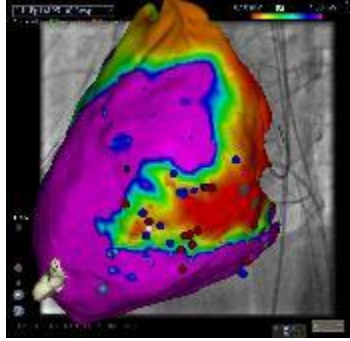


RF termination of VT



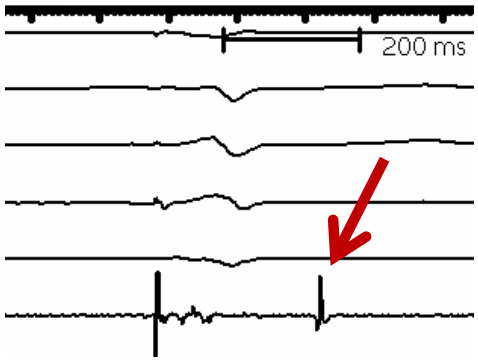
If the clinically relevant VT is no longer inducible should more ablation be done?

Identifying potential channels during sinus or paced rhythm

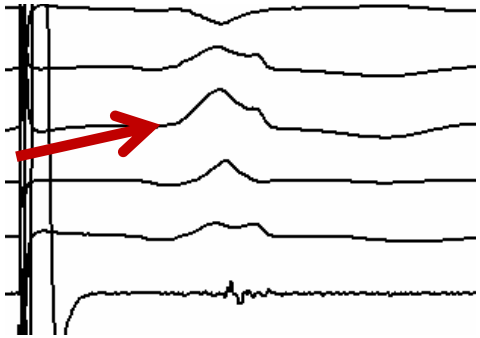


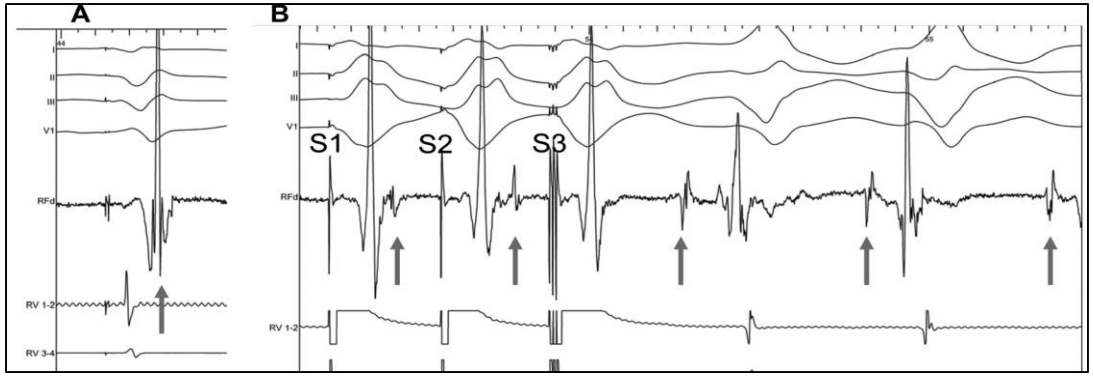
- **Markers of potential channels**

Late potentials



Pace-mapping
Long S- QRS





LAVA = late potentials, or potentials fused with the the far-field ventricular signal during sinus rhythm, that become split potentials with pacing or VT

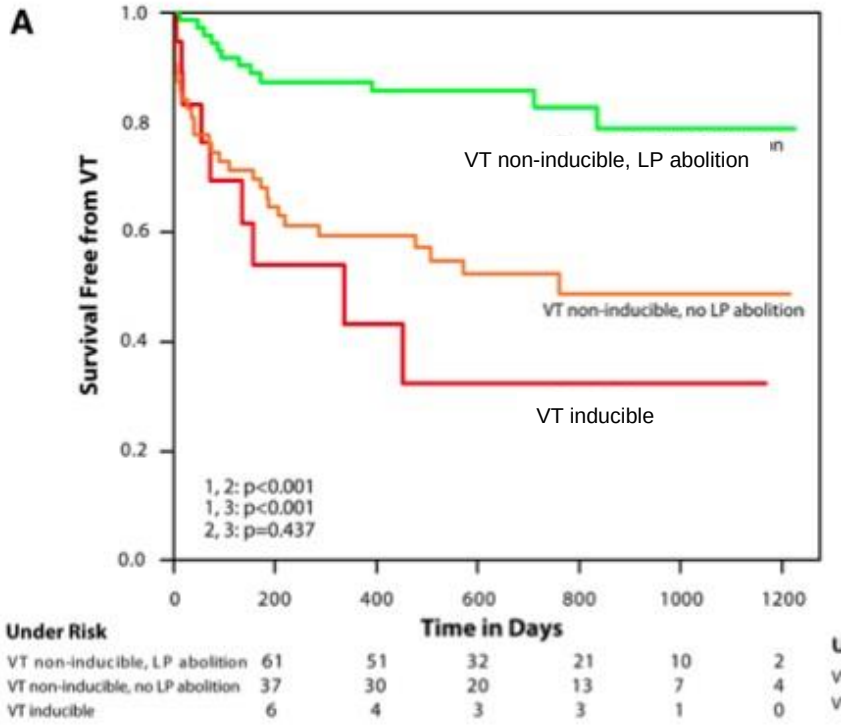
Jaïs P et al. Circulation 2012;125:2184-2196

Noninducibility and Late Potential Abolition: Combined End Point for Catheter Ablation of Postinfarction VT

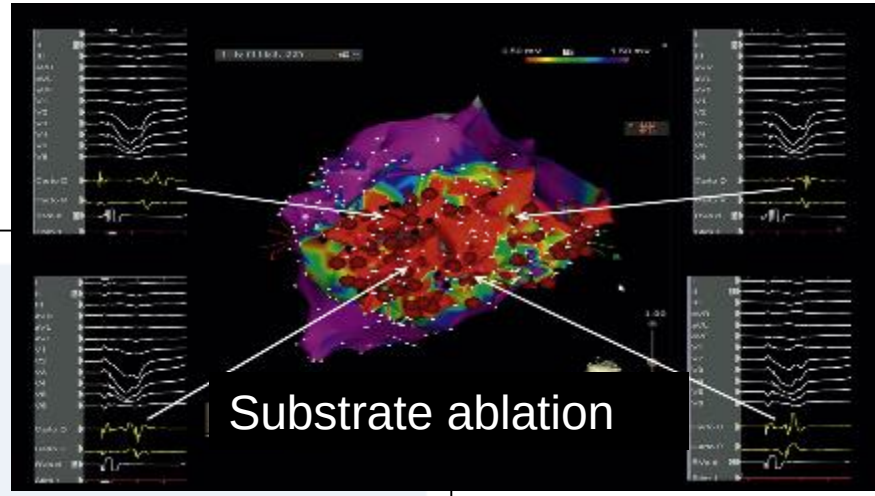
Silberbauer et al Circulation Arrhyth EP 2014

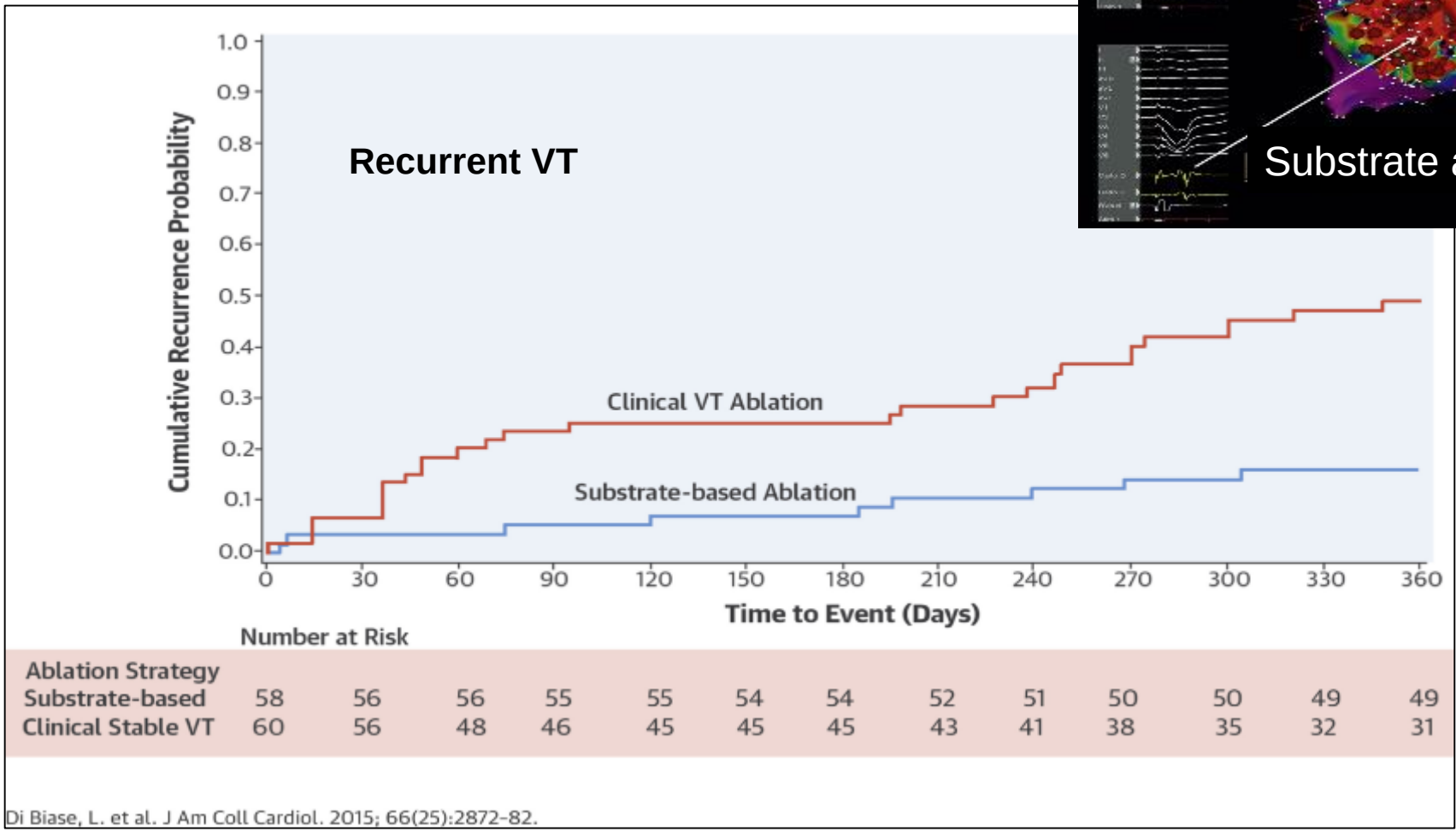
159 post–MI patients undergoing first time ablation.

- 86% had inducible VT at baseline
- 65% had baseline LPs
  - **LPs could not be abolished in 23% of pts with LPs.**
- Follow-up:
  - 32% of pts had recurrent VT
  - abolition of LPs was associated with better outcome



VISTA: extensive substrate ablation vs targeting a clinical VT for hemodynamically tolerated post MI VT





Di Biase, L. et al. J Am Coll Cardiol. 2015; 66(25):2872-82.

Approach to the patient with multiple hemodynamically untolerated VTs

Approaches to Catheter Ablation of Post MI VT

Target Isthmuses /channels of specific VTs

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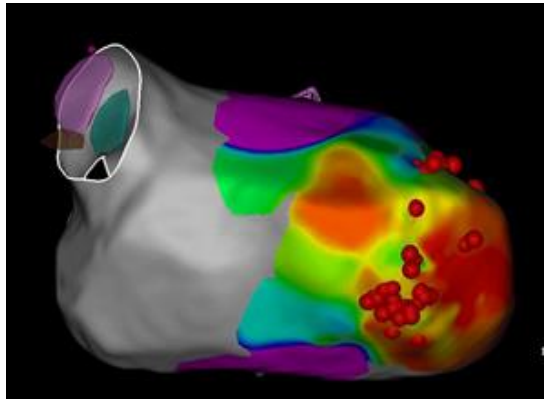
Endpoint
Absence of inducible VT

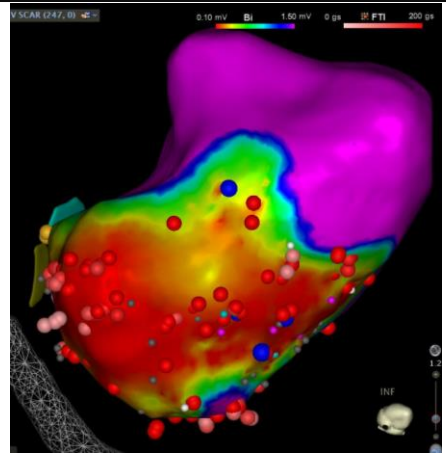


Requires hemodynamic support for extensive mapping of untolerated VTs

Target all potential channels during sinus or paced rhythm

↓

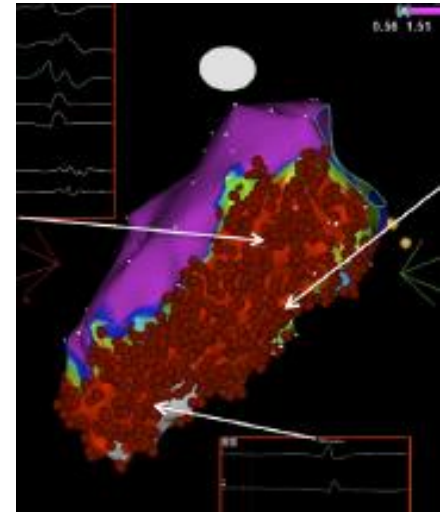
Endpoint
- Absence of inducible VT and LP/LAVA
- core isolation



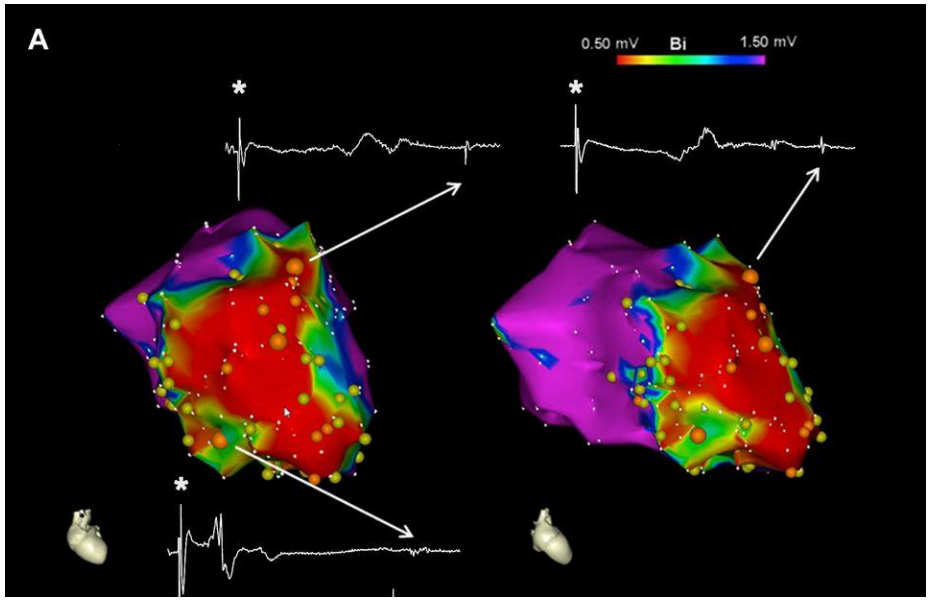
Scar homogenization

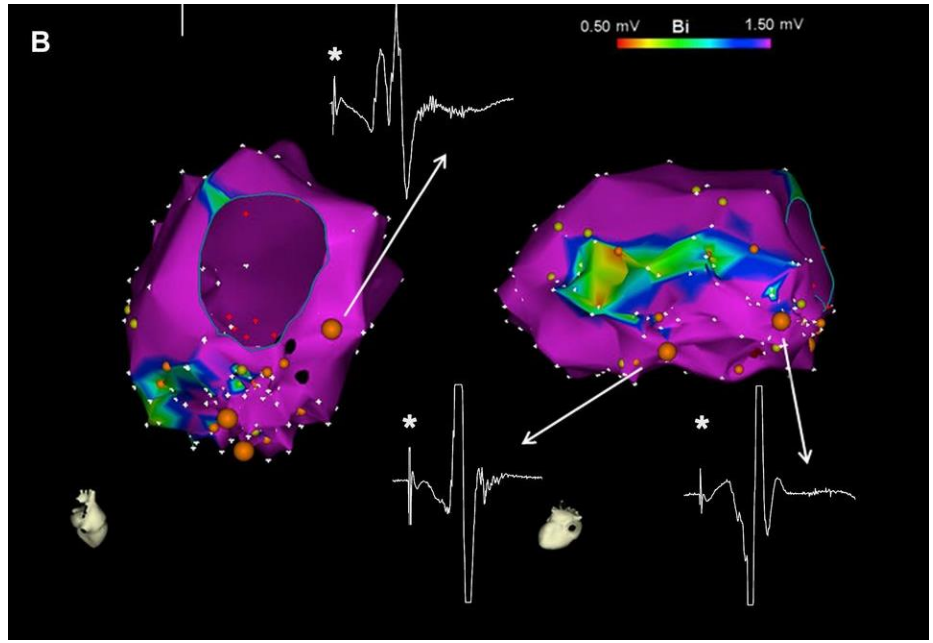
↓

Endpoint
Anatomic coverage of the low voltage area



VT Substrates post MI





Extensive scar

- Large endocardial low bipolar voltage scar (< 1.5 mV)
- Typical of non-reperfused infarcts

Limited endocardial scar

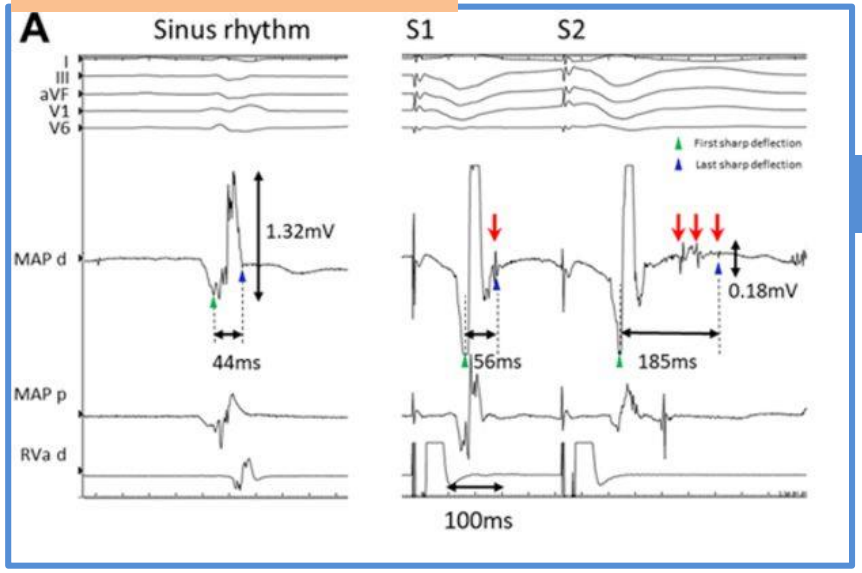
- Small or no endocardial low bipolar voltage scar (< 1.5 mV)
- Typical of effectively reperfused infarcts

Marta de Riva et al. JACEP 2018;4:316-327

Evoked Delayed Potentials: a potential method for identifying VT substrate in borderzone areas

RVA pacing 500 BCL; S2 = ERP + 50

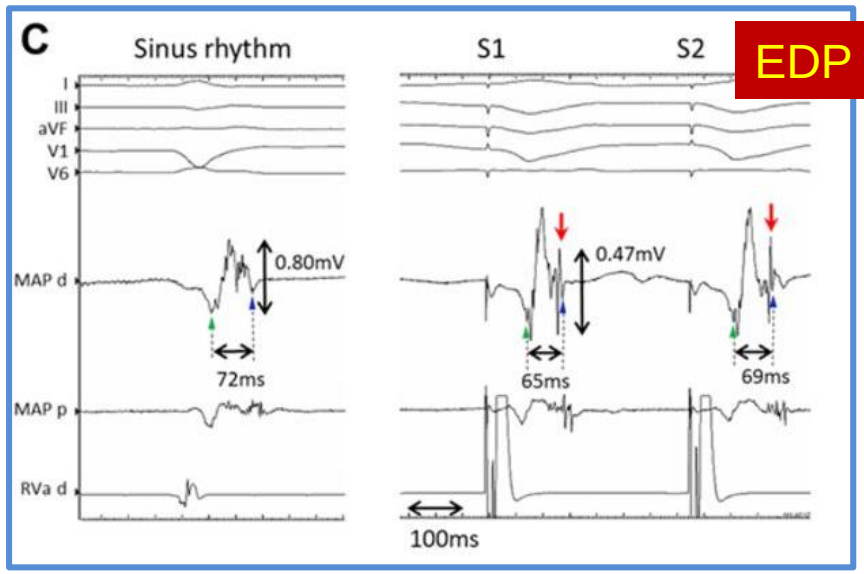
”Hidden Substrate”

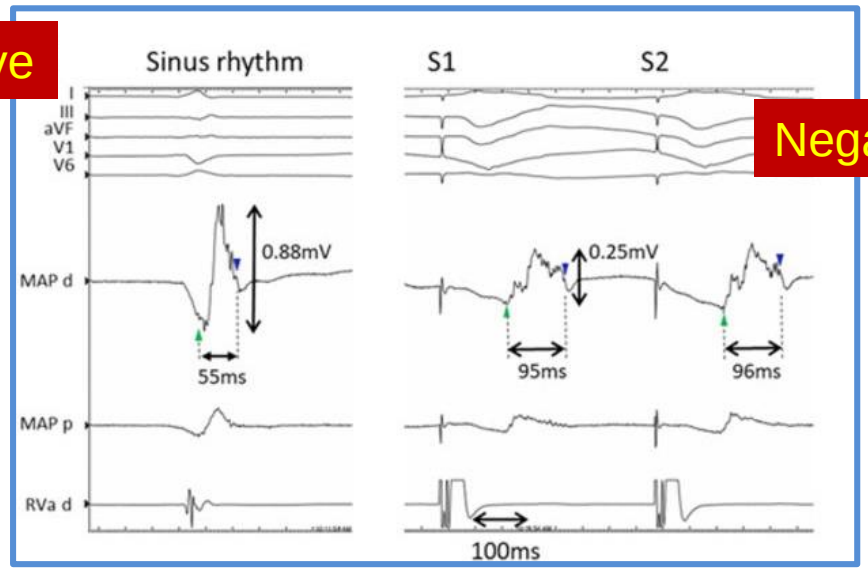


EDP Positive

Evidence of myocyte uncoupling in an area of bipolar voltage > 1.5 mv

EDP Negative



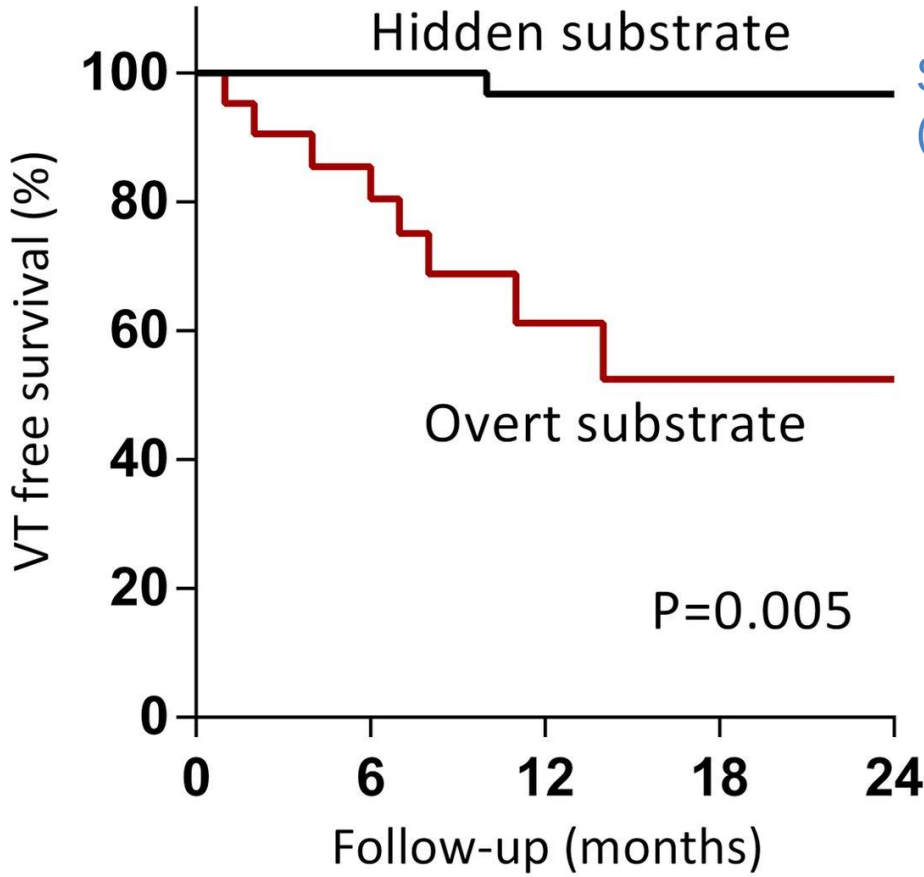


Negative

Marta de Riva et al. JACEP 2018;4:316-327

Targeting the Hidden Substrate Unmasked by Right Ventricular Extrastimulation Improves Ventricular Tachycardia Ablation Outcome After Myocardial Infarction

Ablate EDP then any inducible VT



Scar area (mean): 59 cm2

Scar area (mean): 82 cm2

Patients at risk					
Hidden	37	32	25	12	7
Overt	23	15	7	3	0

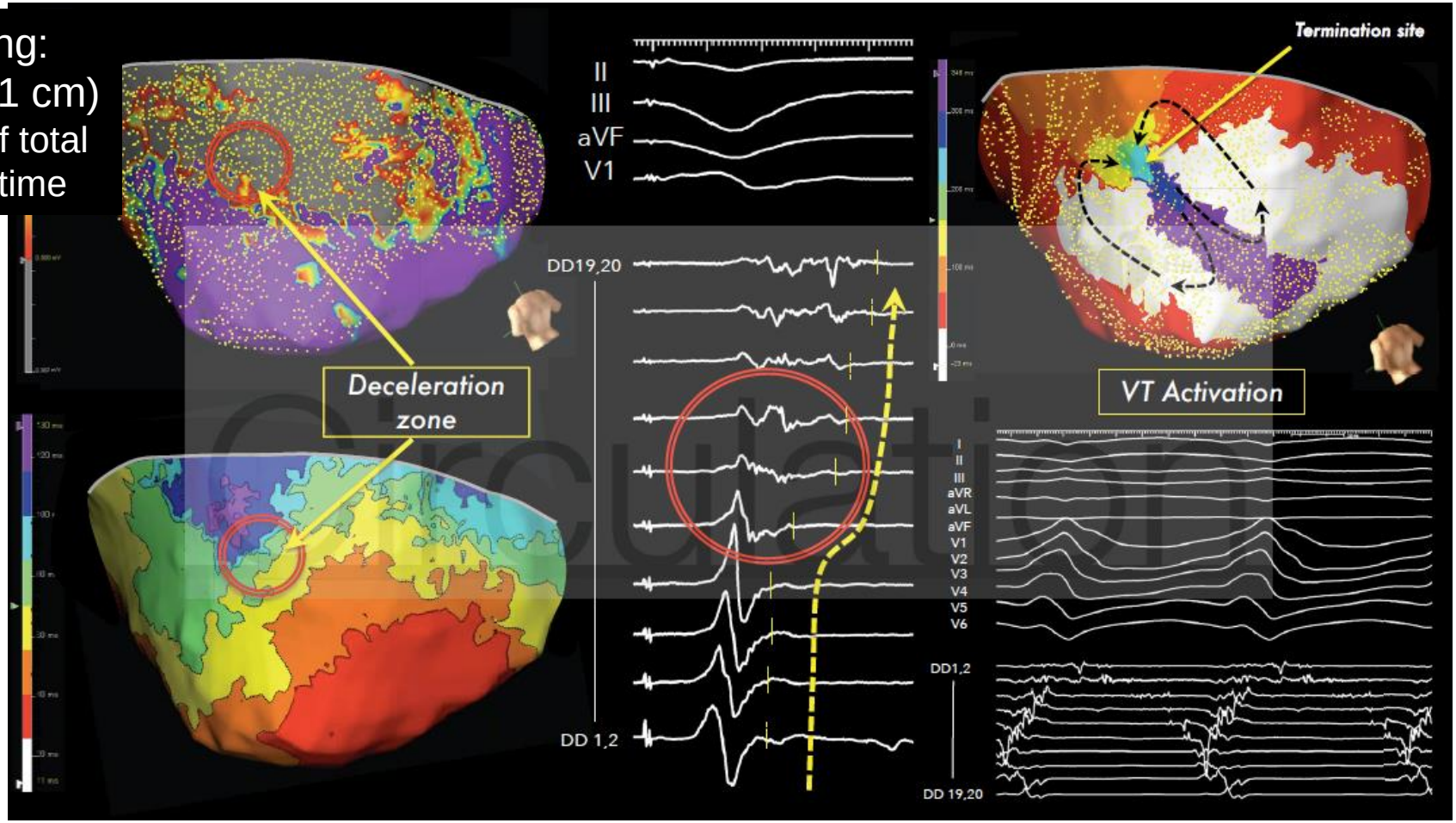
- Median RF: 15 min
- After EDP ablation
  - 67% not inducible
  - 23% received more ablation for inducible VT

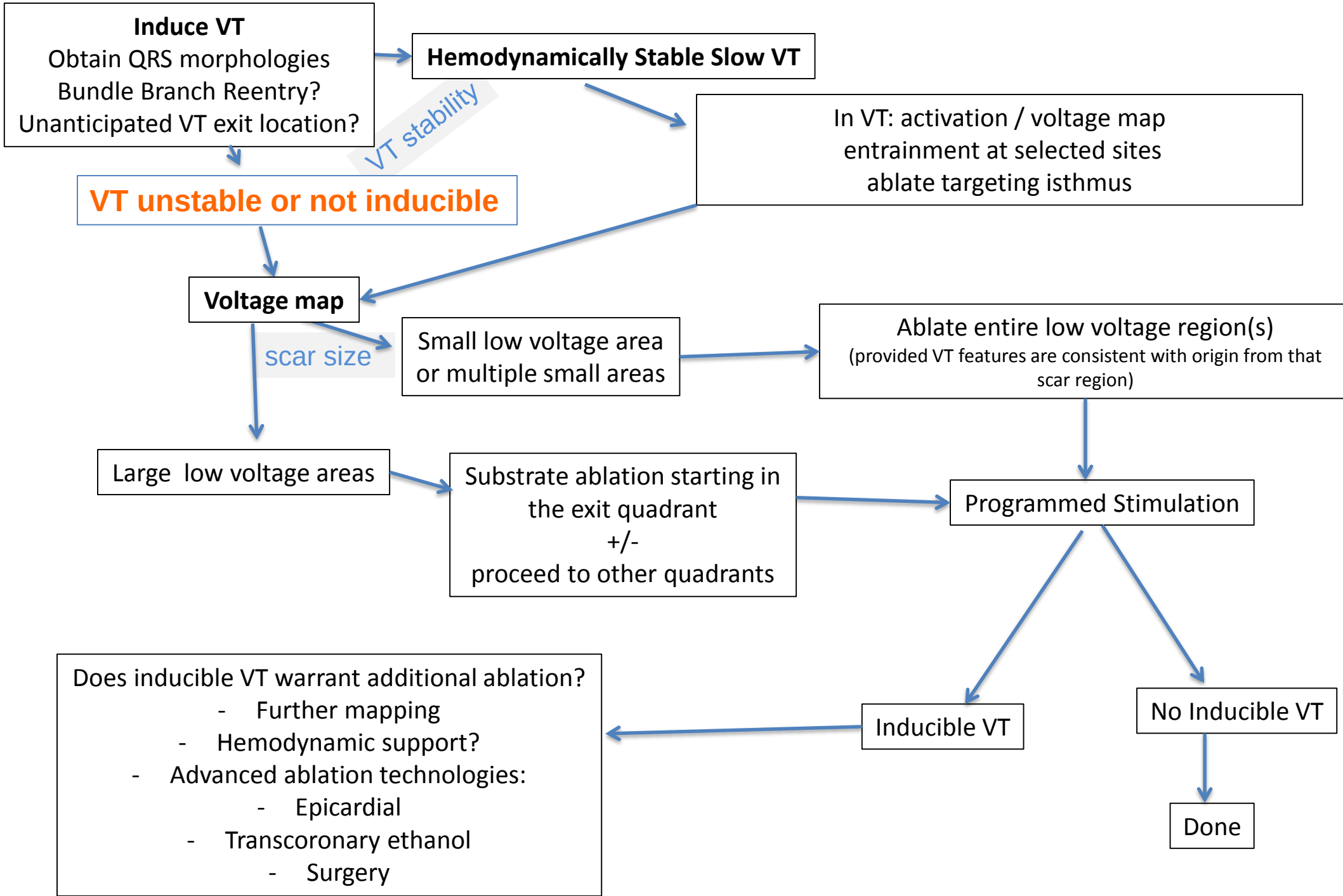
Marta de Riva et al. JACEP 2018;4:316-327

Targeted Ablation of Ventricular Tachycardia Guided by Wavefront Discontinuities During Sinus Rhythm: A New Functional Substrate Mapping Strategy

Aziz, Tung et al Circulation 2019 online

Isochronal crowding:
(3 isochrones within 1 cm)
1 isochrone = 12.5% of total ventricular activation time

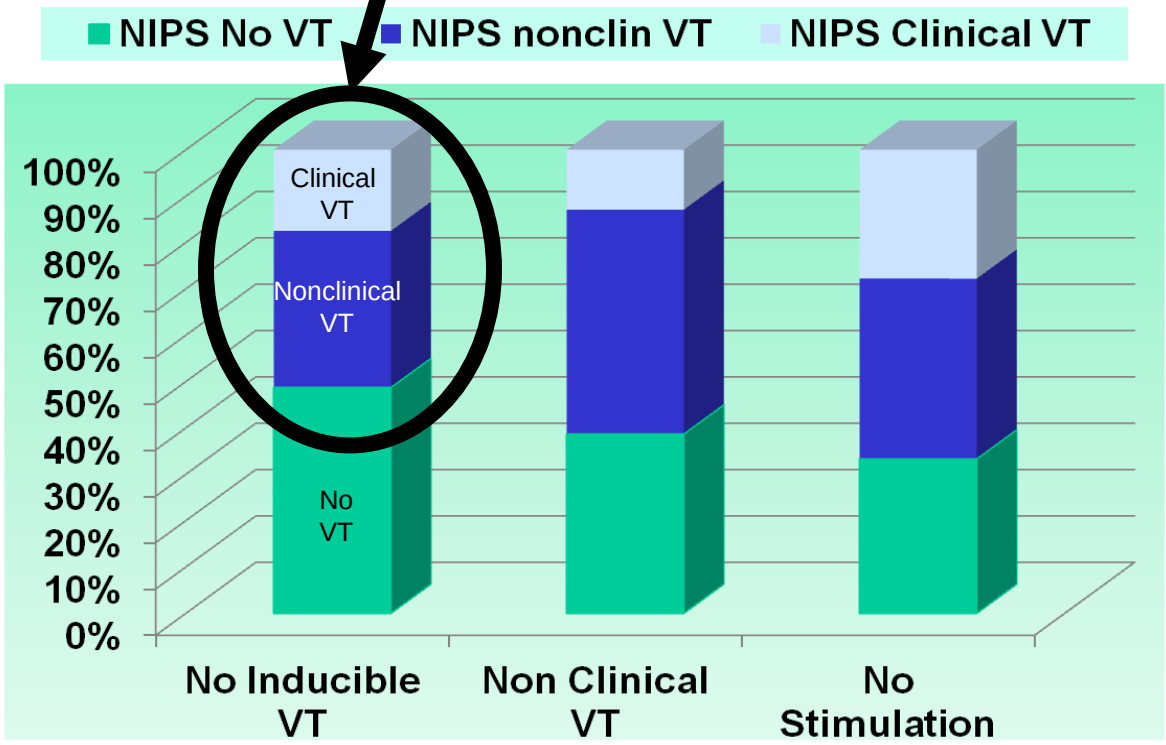



Induce VT
Obtain QRS morphologies
Bundle Branch Reentry?
Unanticipated VT exit location?
Hemodynamically Stable Slow VT
VT stability
In VT: activation / voltage map
entrainment at selected sites
ablate targeting isthmus
VT unstable or not inducible
Voltage map
scar size
Small low voltage area
or multiple small areas
Ablate entire low voltage region(s)
(provided VT features are consistent with origin from that scar region)
Large low voltage areas
Substrate ablation starting in the exit quadrant
+/-
proceed to other quadrants
Programmed Stimulation
Inducible VT
No Inducible VT
Done
Does inducible VT warrant additional ablation?
- Further mapping
- Hemodynamic support?
- Advanced ablation technologies:
- Epicardial
- Transcoronary ethanol
- Surgery

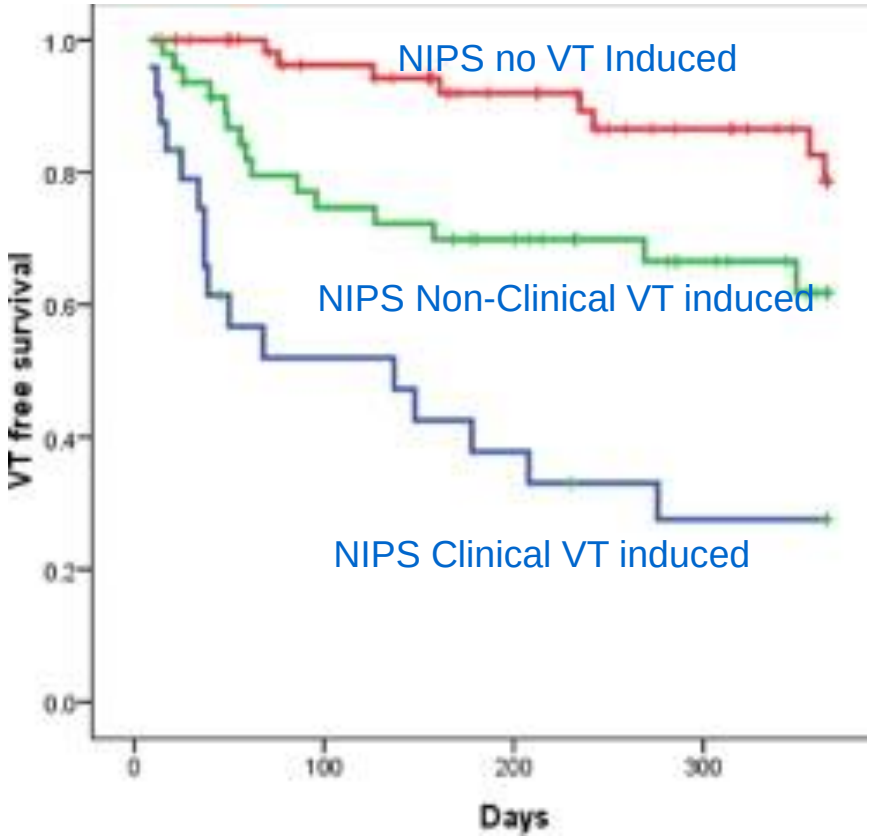
Failure to achieve permanent ablation lesions: Recovery of inducible VT 3 days after ablation

Noninvasive stim (NIPS) 3 days after ablation

NIPS: Programmed stim via ICD pre-discharge



Programmed stim at the end of the ablation procedure

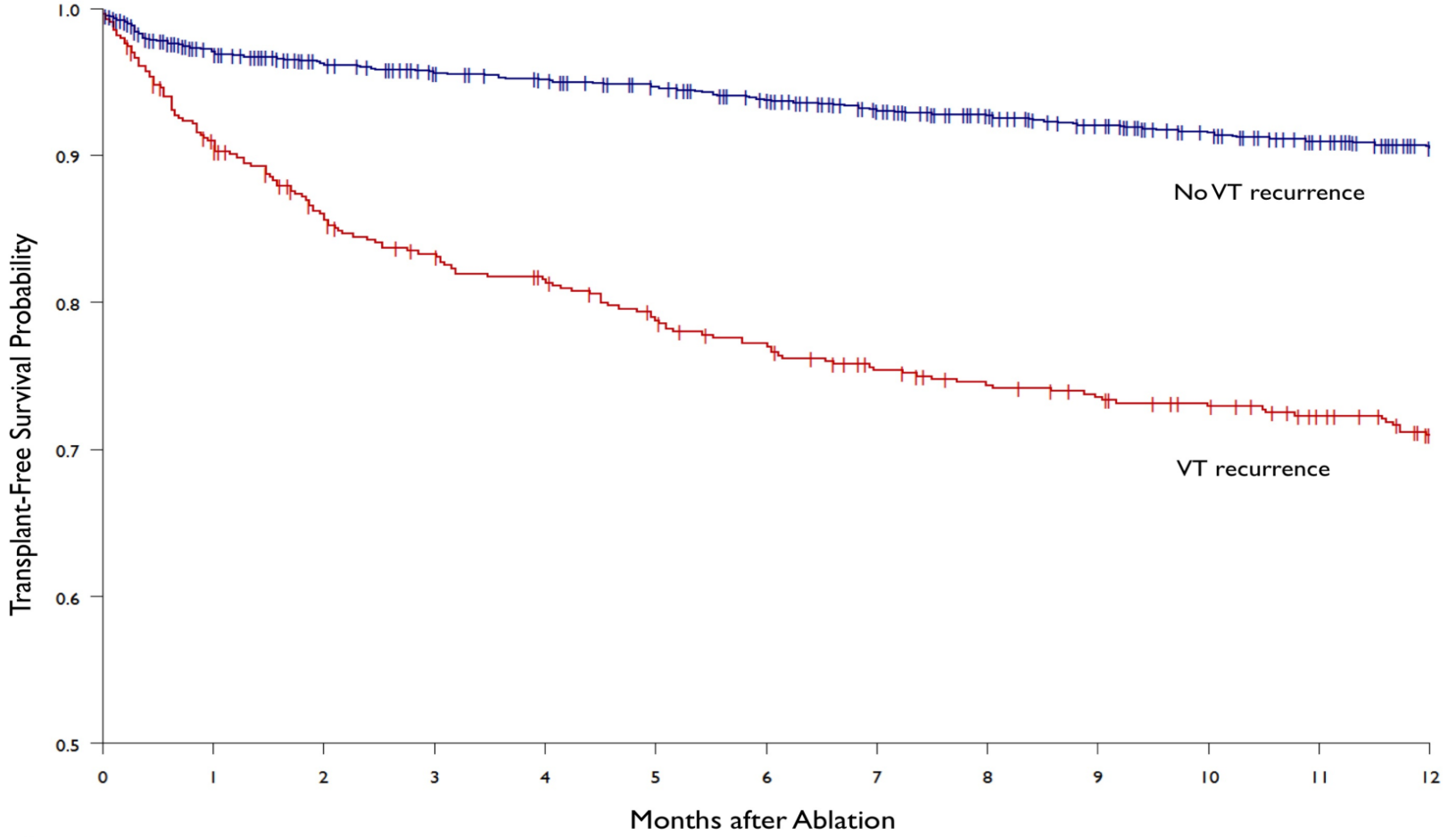


Modified from Frankel et al JACC 2012

Adequate Lesion Creation

- Impedance fall > 10 – 15 Ohms
- Tissue whitening on intracardiac ultrasound
- Unexcitable to pacing at 10 ma 2ms

Recurrent VT after catheter ablation is associated with mortality/transplantation, (independent of EF and heart failure status).



Number at risk:							
	1,525	1,278	1,241	1,194	1,134	1,087	1,024
	536	445	415	387	363	346	321

The IVTCC Investigators: Freedom From Ventricular Tachycardia after Catheter Ablation Is Associated With Improved Survival in Patients With Structural Heart Disease: Heart Rhythm 2015 (in press) http://dx.doi.org/10.1016/j.hrthm.2015.05.036

Complications of VT ablation in structural heart disease

Tung et al Heart Rhythm 2015

Patients	2061
Complications	6%
Death	0.1%
Vascular access	1.6%
Hemopericardium	1.7%
AV block	0.9%
Stroke/TIA	0.5%
coronary injury	0.2%

Antiarrhythmic Drug Escalation vs Ablation for recurrent VT in CAD

259 patients

- Prior MI, ICD, recurrent VT
- One of the Following VT Events despite drug therapy
  - ≥ 3 episodes VT treated with ATP, with symptoms
  - ≥ 1 appropriate ICD shock
  - ≥ 3 VT episodes within 24 hours
  - Sustained VT below programmed ICD detection

Randomization
stratified for center and amiodarone at study entry

Escalated Drug Therapy

Sotalol → Amiodarone load then 200 mg/d

Amiodarone <300 → Amio reload, then 300 mg/d

Amio ≥300 mg/d → Amio + Mexiletine 600 mg/d

Ablation

continue same drug

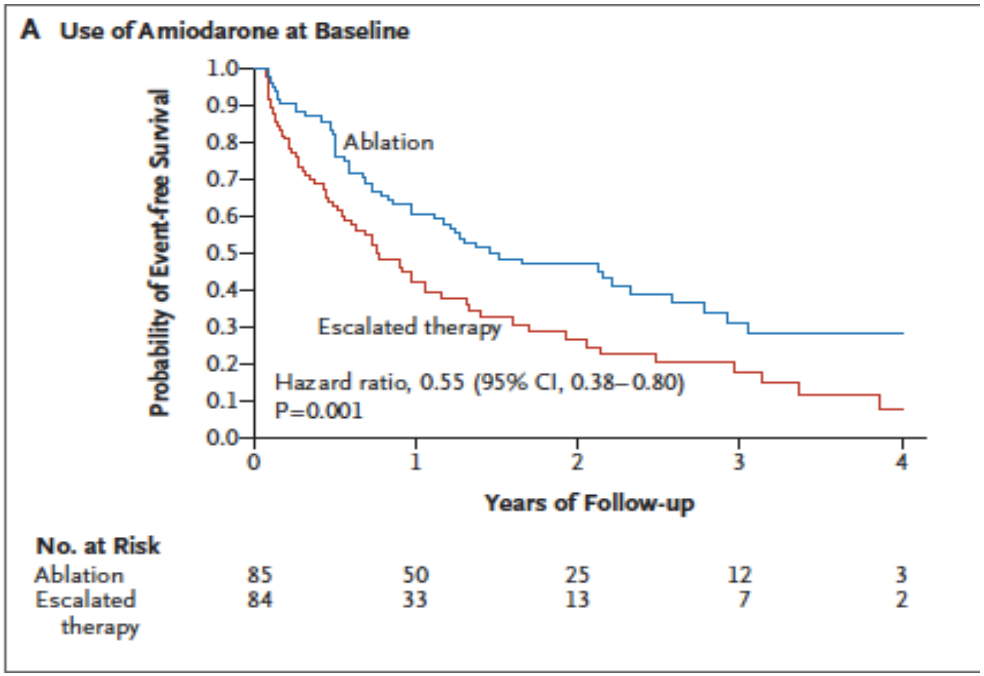
Sapp et al NEJM 2016

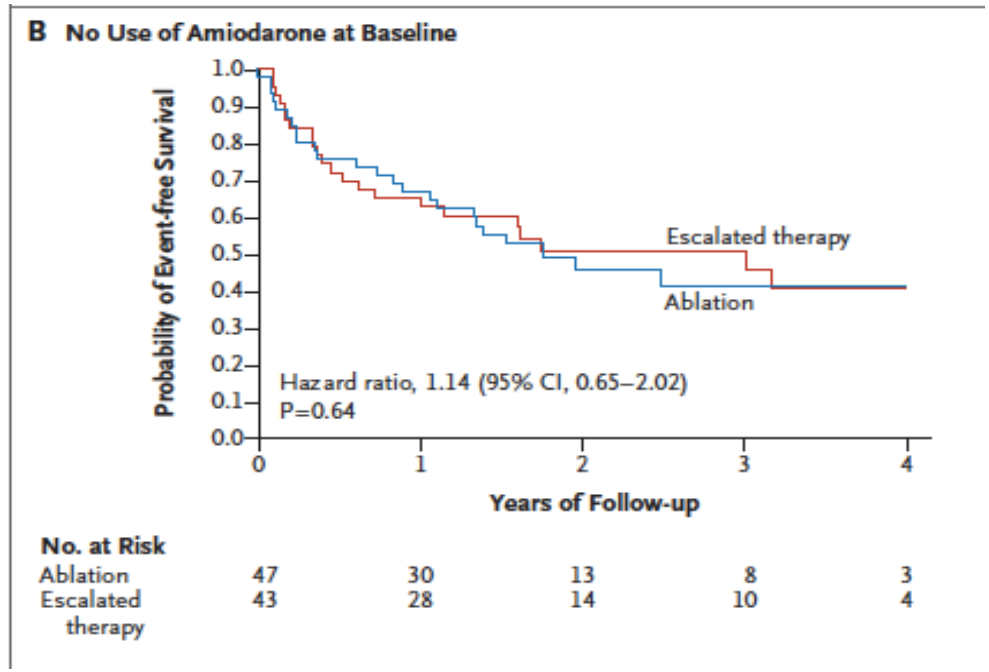
VANISH Trial Sapp et al NEJM 2015

Subgroup analysis

VT on amio –
VT ablation superior to increasing amiodarone or adding mexiletine to amiodarone

VT on sotalol –
ablation has similar efficacy to amiodarone





Primary Outcome: Death, VT Storm, Appropriate Shock

Treatment-Attributable Adverse Events

Event	Drug Group (n=127) No. (%)	Catheter Ablation (n=132) No. (%)	P
Catheter Ablation Related			
Vascular injury		3 (2.3)	0.25
Major Bleeding	1 (0.8)	3 (2.3)	0.62
Cardiac Perforation	1 (0.8)	2 (1.5)	1.00
Endocarditis	1 (0.8)		0.49
Heart Block	1 (0.8)		0.49
Antiarrhythmic Drug Related			
Death			
Pulmonary toxicity	**2 (1.6)**		**0.24**
Liver toxicity/multiorgan failure	**1 (0.8)**		**0.49**
Pulmonary Infiltrate	2 (1.6)		0.24
Shortness of Breath	3 (2.4)	1 (0.8)	0.36
Heart Failure Admission	1 (0.8)	3 (2.3)	0.62
Hyperthyroidism	5 (3.9)	3 (2.3)	0.49
Hypothyroidism	5 (3.9)	2 (1.5)	0.27
Hepatic Dysfunction	6 (4.7)		0.013
Tremor/Ataxia	6 (4.7)		0.013
SFX Leading To Drug Therapy Change	6 (4.7)		0.013
Other adverse events no. (%)	6 (4.7)	4 (3.0)	0.53
TOTAL PATIENTS	39 (30.7)	20 (15.2)	0.0031
TOTAL EVENTS	51	22	0.0023

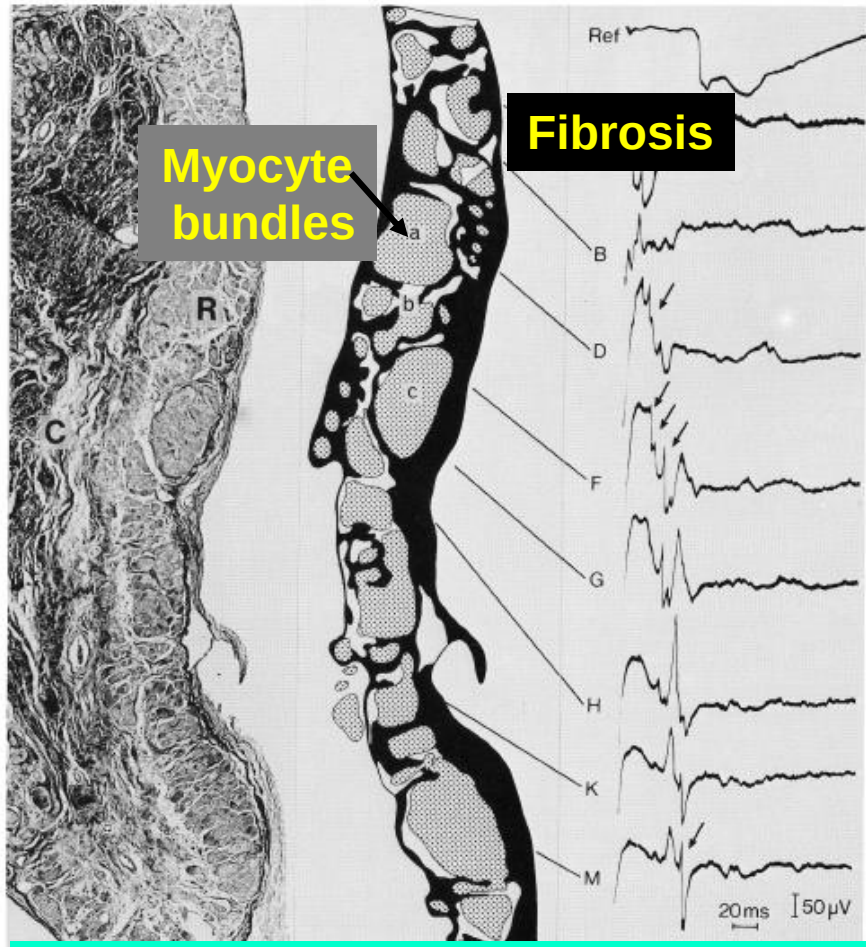
Catheter Ablation for VT due to prior Myocardial Infarction

- Important therapy for patients with recurrent VT
- Acceptable risk
- Strategies continue to evolve
- Inability to achieve durable lesions is a limitation

Thank you

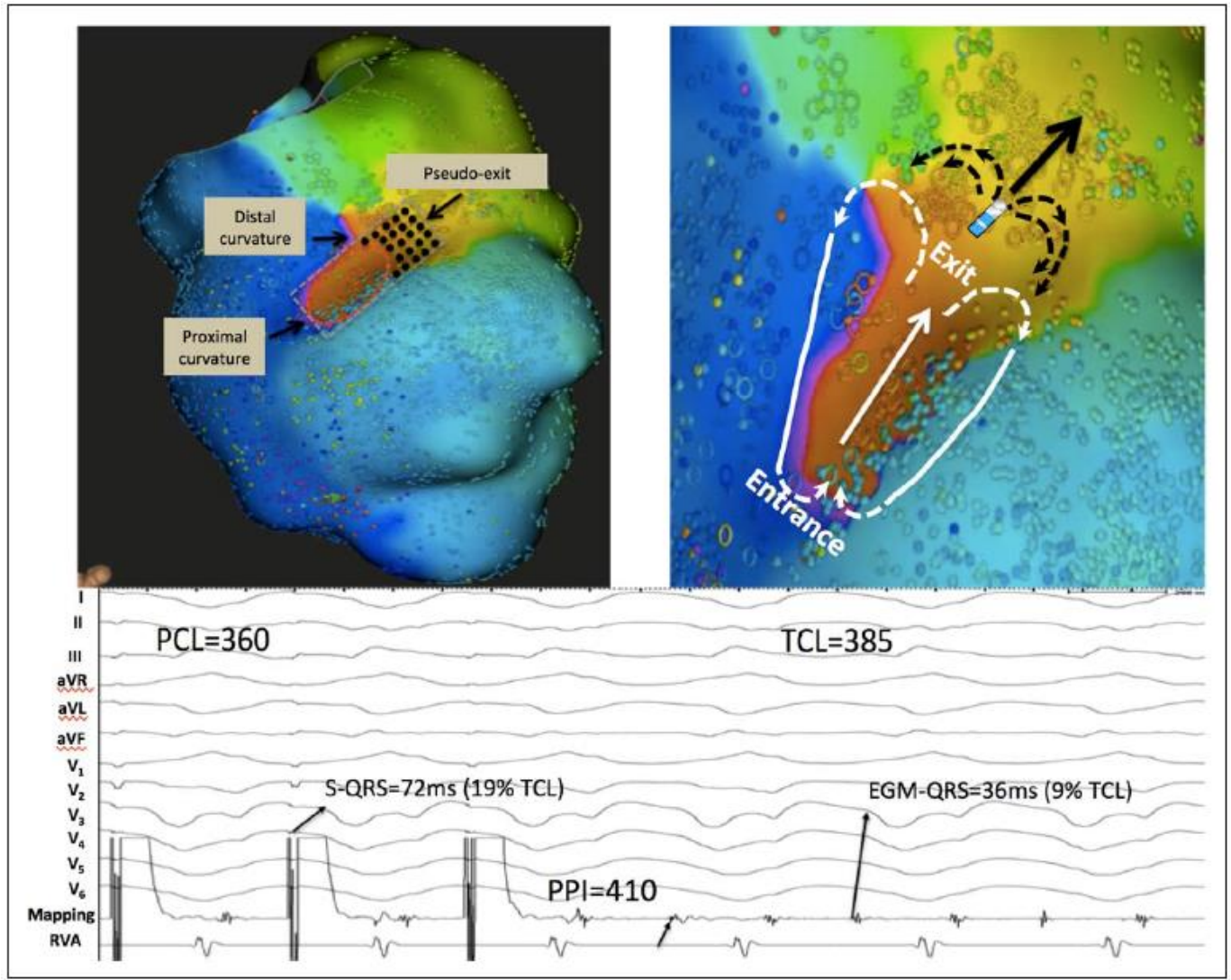
Slow conduction: Zig - zag conduction caused by fibrotic separation of myocyte bundles

De Bakker, et al. Circulation 1988; 77:589. Circulation 1993;88:915.



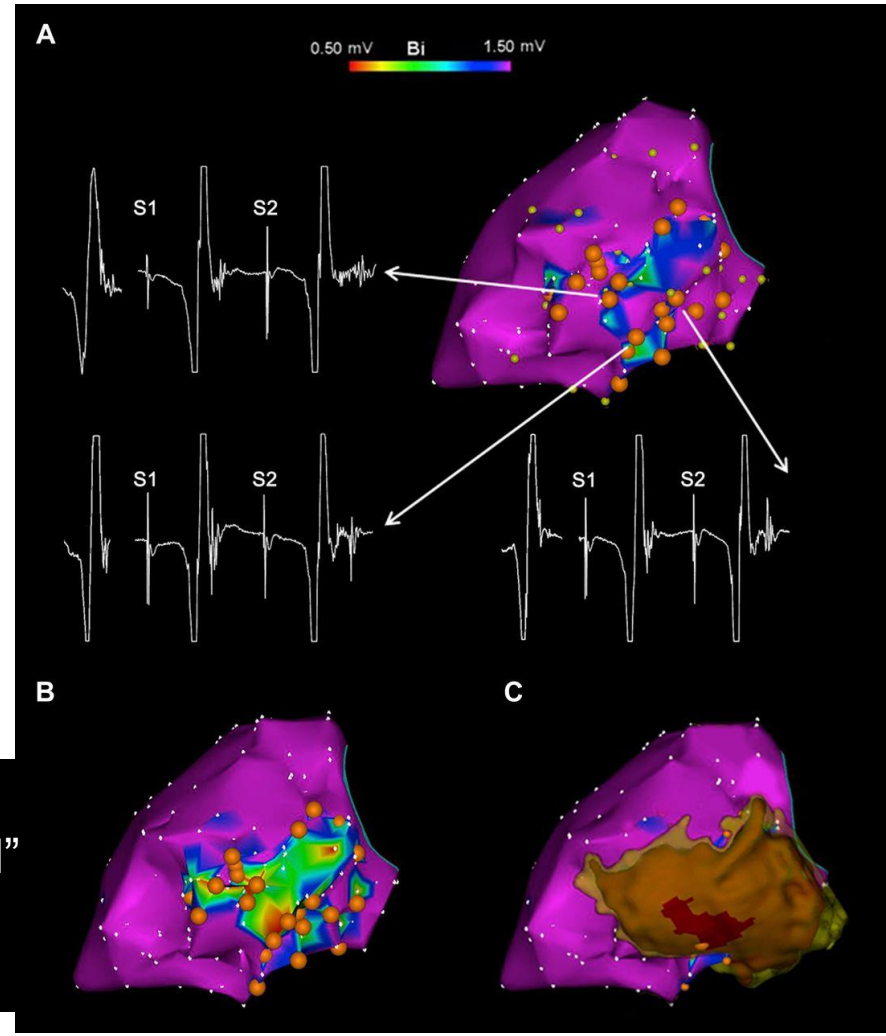
Human papillary muscle in cross section

Entrainment with concealed fusion and PPI – TCL < 30 mms near but outside the isthmus exit of functionally defined reentry circuits



Anter et al Circulation 2016

Ablation at evoked delayed potential sites



Bipolar voltage excluding “far-field” high voltage signals

Delayed hyperenhancement area from cardiac MR imaging

Marta de Riva et al. JACEP 2018;4:316-327

Many studies of substrate guided ablation incorporate mapping during VT

Elimination of Local Abnormal Ventricular Activities
A New End Point for Substrate Modification in Patients With Scar-Related Ventricular Tachycardia

Jais et al Circulation 2012

"In patients in whom at least 1 VT was inducible and well tolerated (ie, 11 during the first intervention, 3 during subsequent interventions), ablation was guided by conventional entrainment mapping criteria to identify the critical isthmus."

Noninducibility and Late Potential Abolition: A Novel Combined Prognostic Procedural End Point for Catheter Ablation of Postinfarction Ventricular Tachycardia

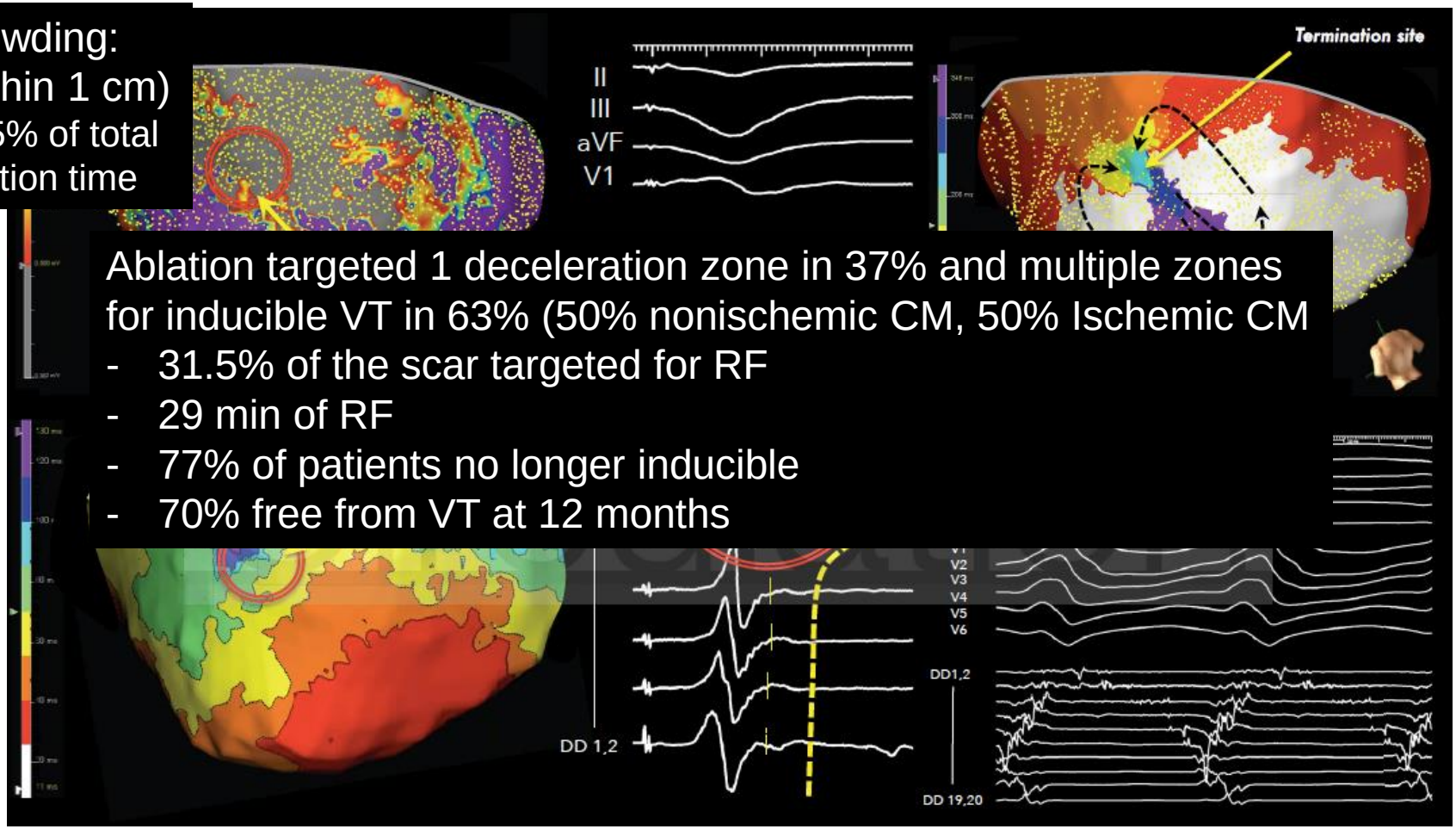
Silberget et al Circ Arrhythm Electrophysiol 2014

"In patients with tolerated or hemodynamically supportable VT, VT was ablated using activation and entrainment mapping. After VT termination, ablation continued in SR aiming at the complete abolition of LPs (1A) when present or EPs when absent (1B)."

Targeted Ablation of Ventricular Tachycardia Guided by Wavefront Discontinuities During Sinus Rhythm: A New Functional Substrate Mapping Strategy

Aziz, Tung et al Circulation 2019 online

Isochronal crowding:
(3 isochrones within 1 cm)
1 isochrone = 12.5% of total ventricular activation time



Ablation targeted 1 deceleration zone in 37% and multiple zones for inducible VT in 63% (50% nonischemic CM, 50% Ischemic CM

- 31.5% of the scar targeted for RF
- 29 min of RF
- 77% of patients no longer inducible
- 70% free from VT at 12 months