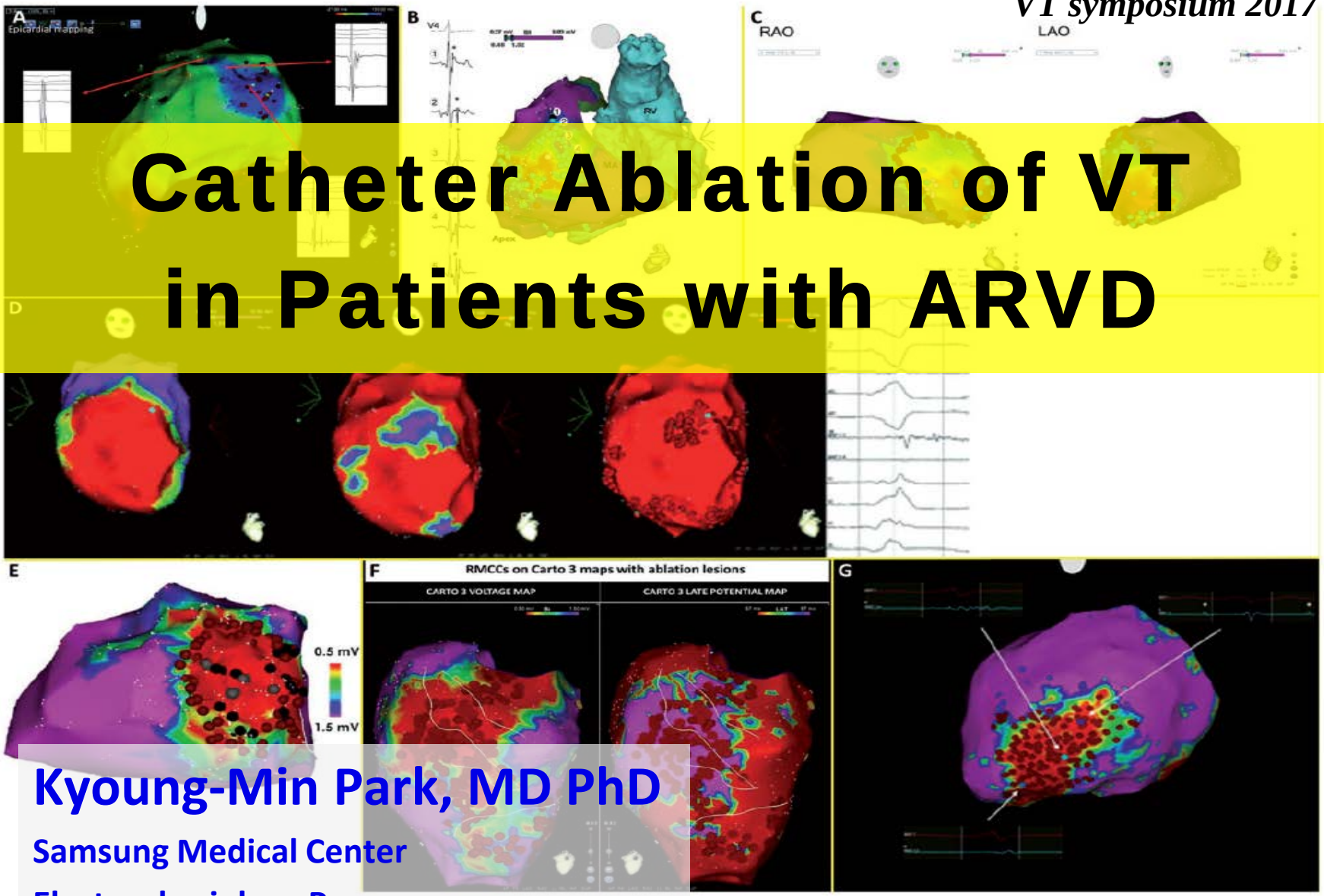
Catheter Ablation of VT in Patients with ARVD



Kyoung-Min Park, MD PhD

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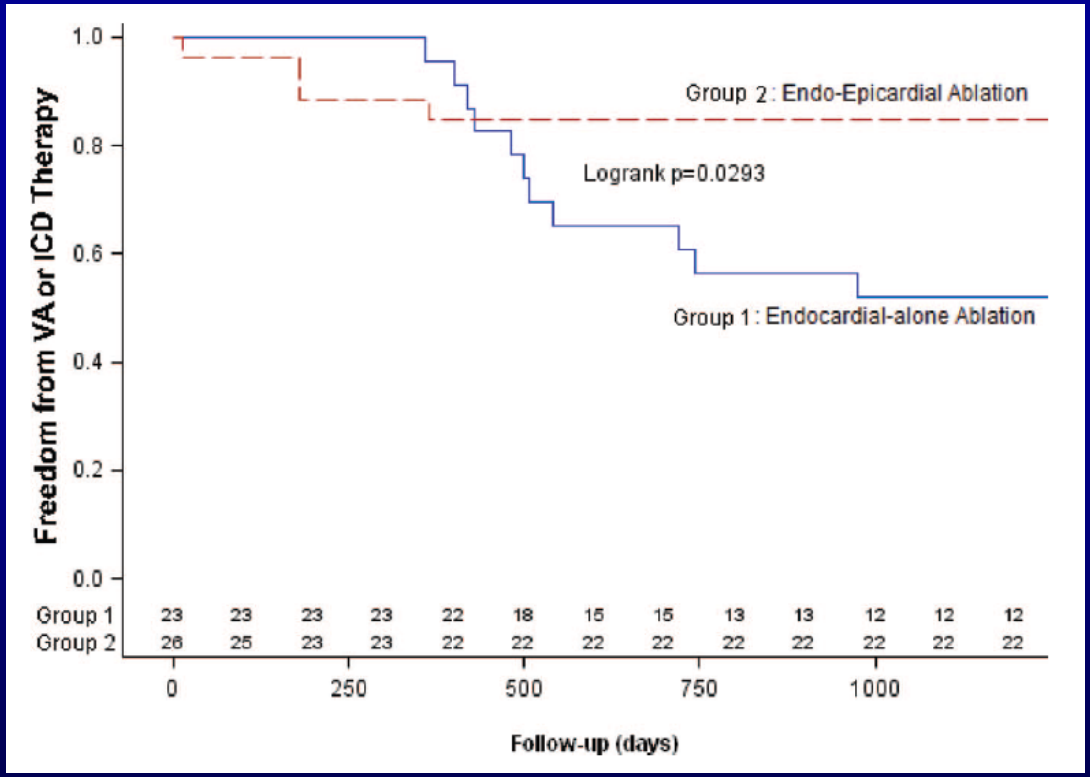
Figure 3 Strategies for substrate modification of studies included (*A*) local abnormal ventricular activities, (*B*) scar dechanneling, (*C*) substrate isolation, (*D*) late potentials, (*E*) core isolation, (*F*) ripple mapping conduction channels, (*G*) scar homogenization. Adapted from Jais et al.[5], Vergara et al.[7], Tilz et al.[13], Berruezo et al.[9], Tzou et al.[12], Jamil-Copley et al.[14], Gokoglan et al.[15]

Ablation of Ventricular Arrhythmias in Arrhythmogenic Right Ventricular Dysplasia/Cardiomyopathy

Arrhythmia-Free Survival After Endo-Epicardial Substrate Based Mapping and Ablation

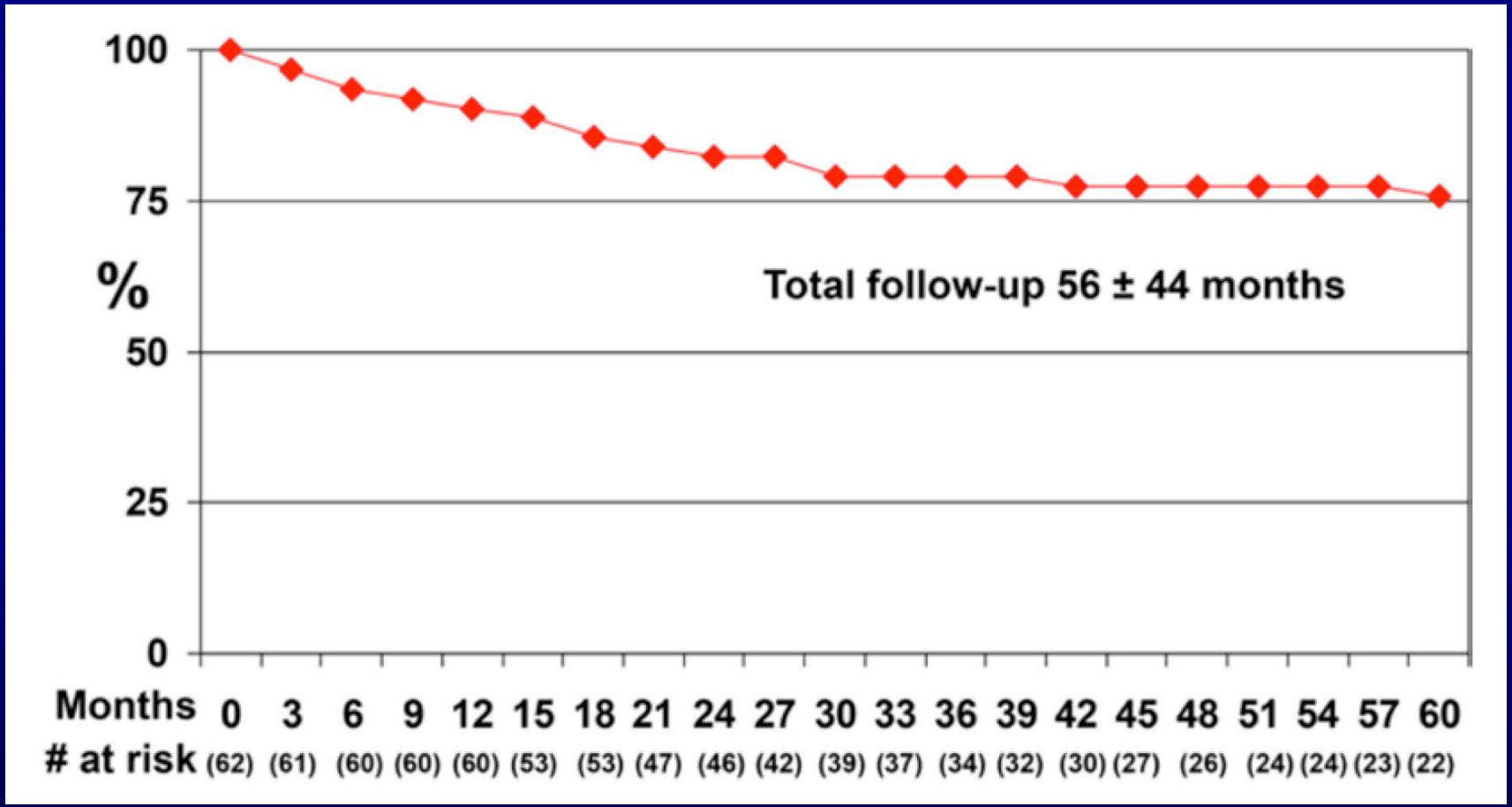
Rong Bai, MD, FHRS*; Luigi Di Biase, MD, PhD, FHRS*; Kalyanam Shivkumar, MD; Prasant Mohanty, MBBS, MPH; Roderick Tung, MD; Pasquale Santangeli, MD; Luis Carlos Saenz, MD; Miguel Vacca, MD; Atul Verma, MD; Yariv Khaykin, MD; Sanghamitra Mohanty, MD; J. David Burkhardt, MD, FHRS; Richard Hongo, MD; Salwa Beheiry, RN; Antonio Dello Russo, MD; Michela Casella, MD; Gemma Pelargonio, MD; Pietro Santarelli, MD; Javier Sanchez, MD; Claudio Tondo, MD; Andrea Natale, MD, FHRS



Bai R et al. Circ Arrhythm Electrophysiol. 2011;4:478–485

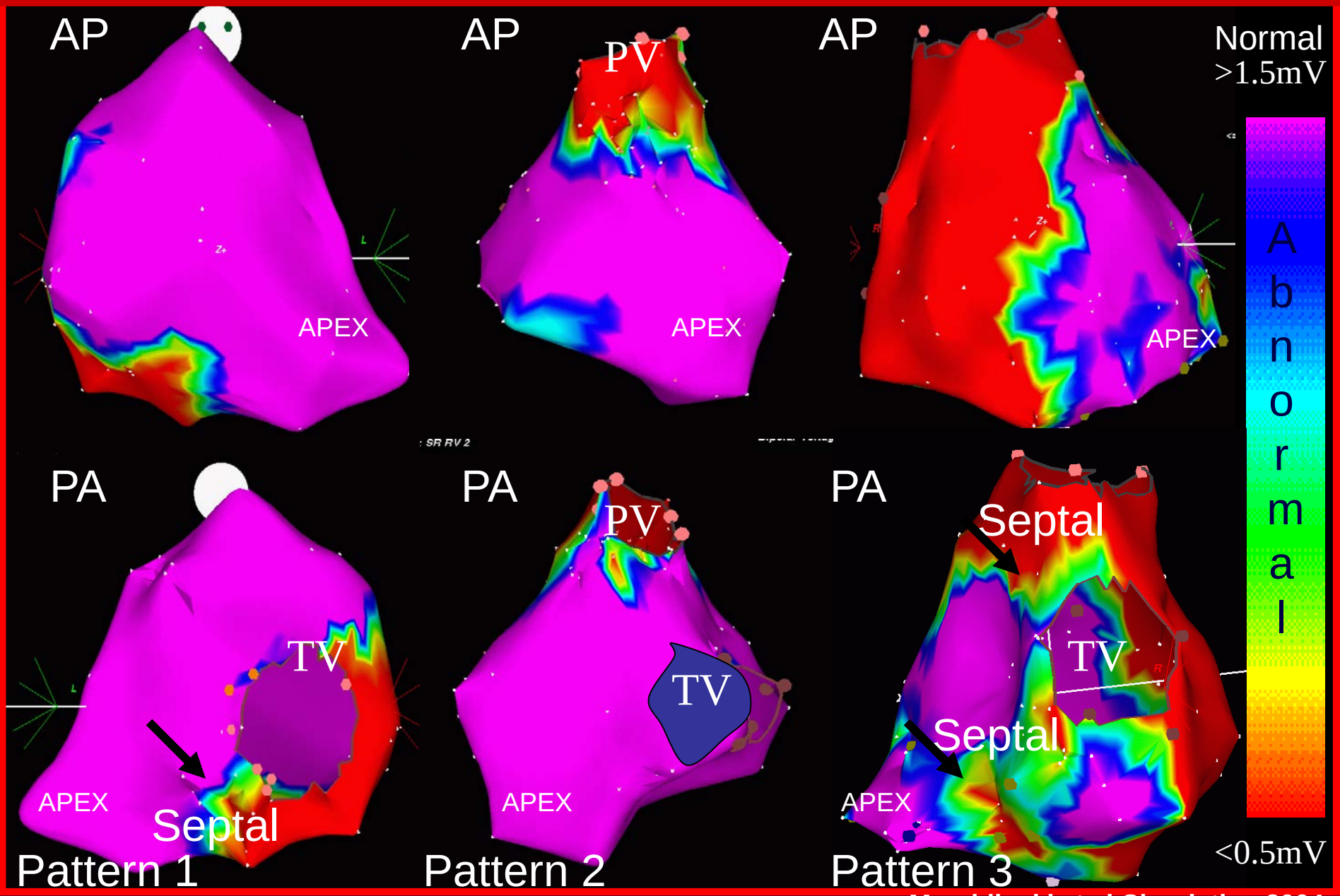
Long-Term Outcome With Catheter Ablation of Ventricular Tachycardia in Patients With Arrhythmogenic Right Ventricular Cardiomyopathy

Kaplan-Meier curve: freedom from any sustained VT



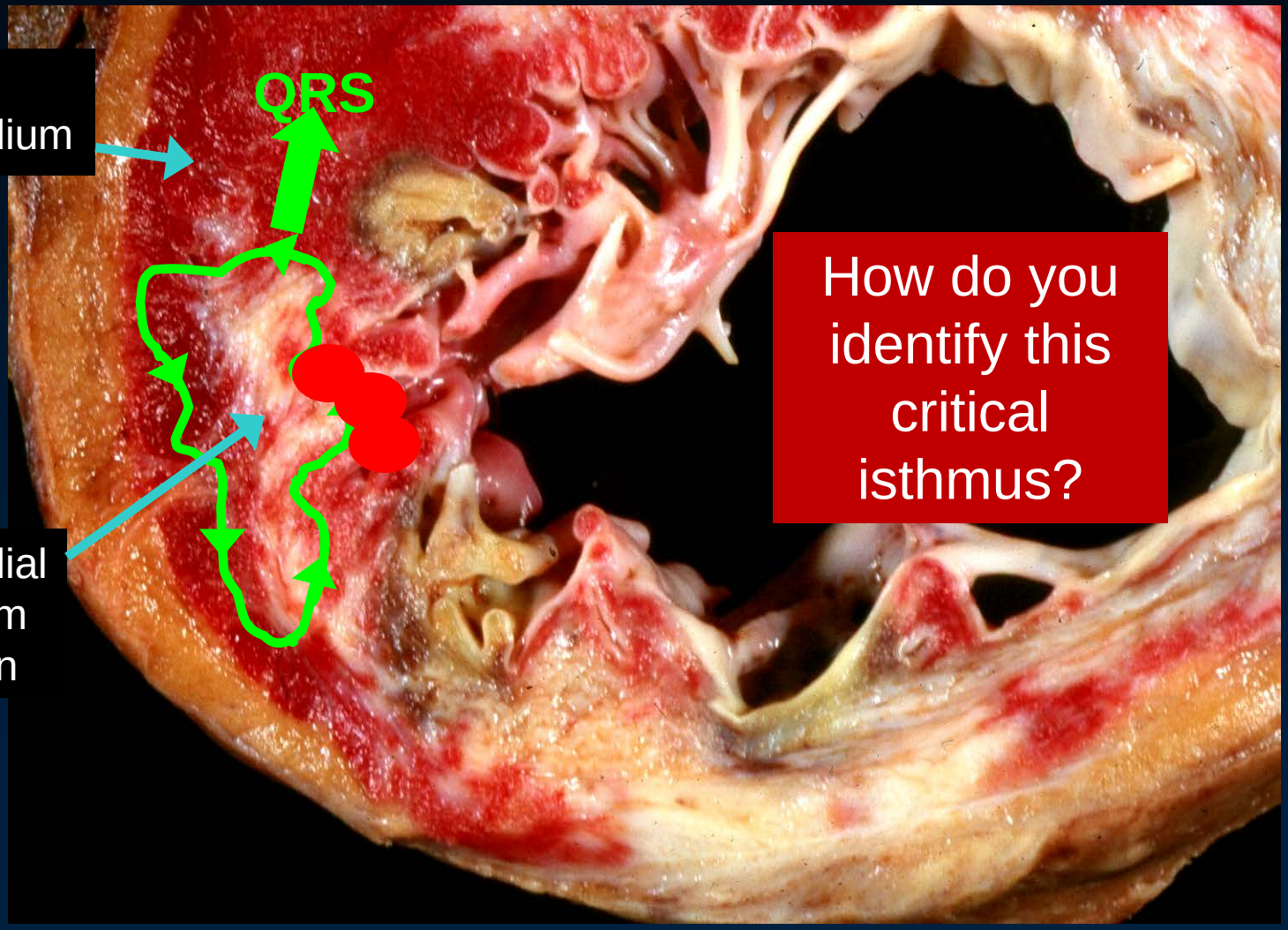
Santangeli P et al. Circ Arrhythm Electrophysiol. 2015;8:1413-1421

BIPOLAR VOLTAGE MAPS - SUBSTRATE IN PATIENTS WITH RV CARDIOMYOPATHY AND VT

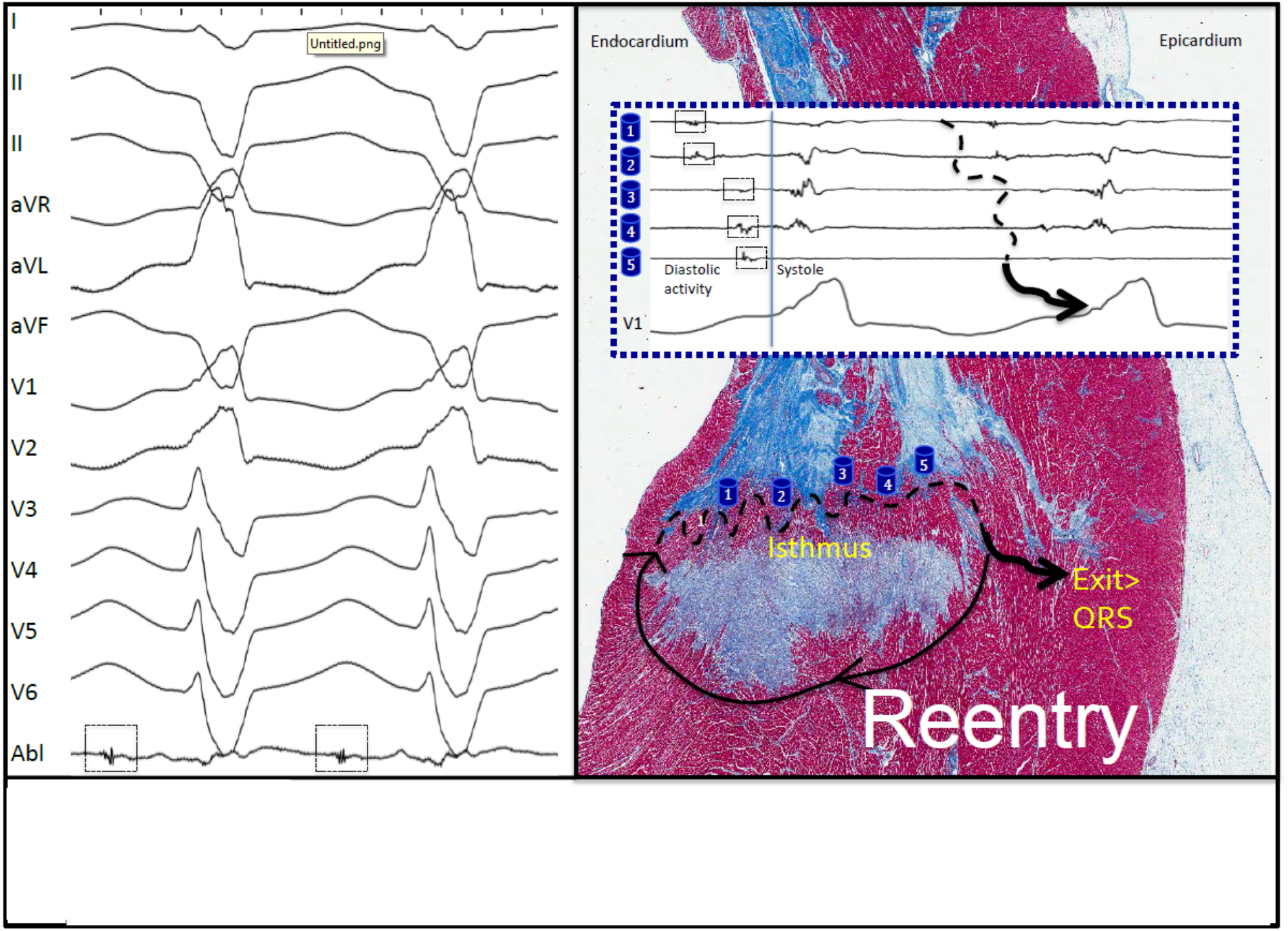


Marchlinski et al Circulation 2004

Endocardial VT Ablation – Tolerated VT – Target critical Isthmus



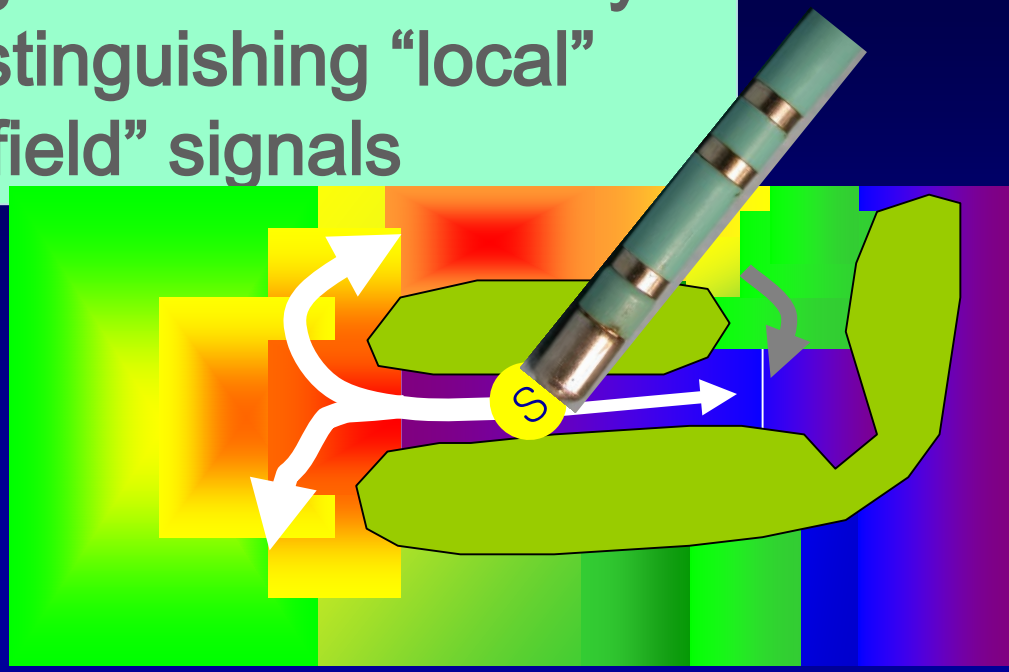
Pathology Photo courtesy of Dr. William Stevenson

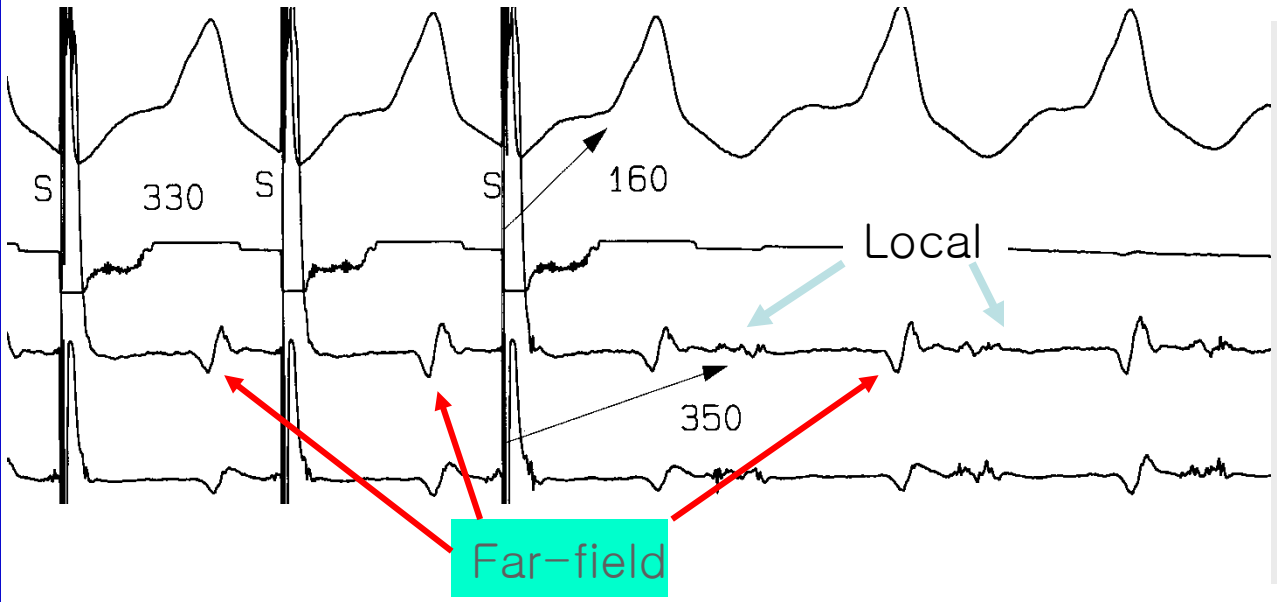


Courtesy of Dr Tung, University of Chicago. Tung R, Boyle NG, Shivkumar K. Catheter ablation of ventricular tachycardia. *Circulation*. 2011;123(20):2284-2288

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.

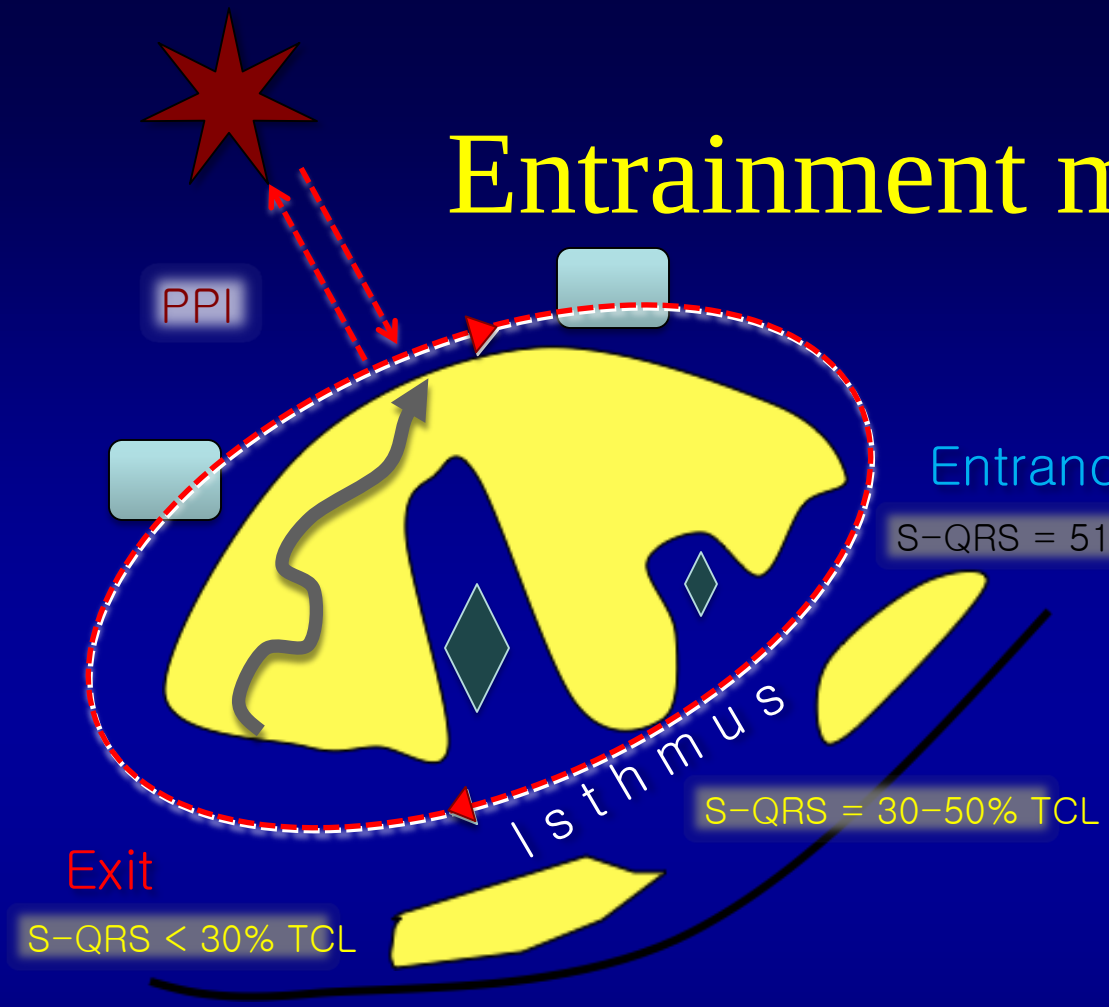




Far-field signal visible and separate from pacing stimulus

Local signal obscured during pacing with capture

Entrainment mapping



Scar

Pacing site

Bystander

Outer Loop

Inner Loop

Isthmus

- Concealed
- PPI = TCL ± 30ms or S-QRS = EGM-QRS ±20ms

Inner Loop

- Concealed
- S-QRS > 70% TCL

Outer Loop

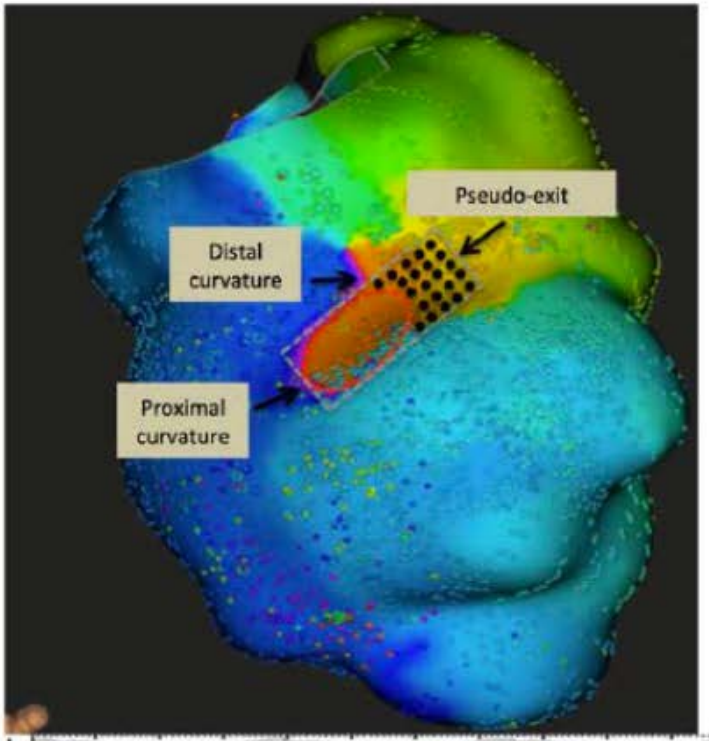
- Manifest Fusion
- PPI = TCL ± 30ms

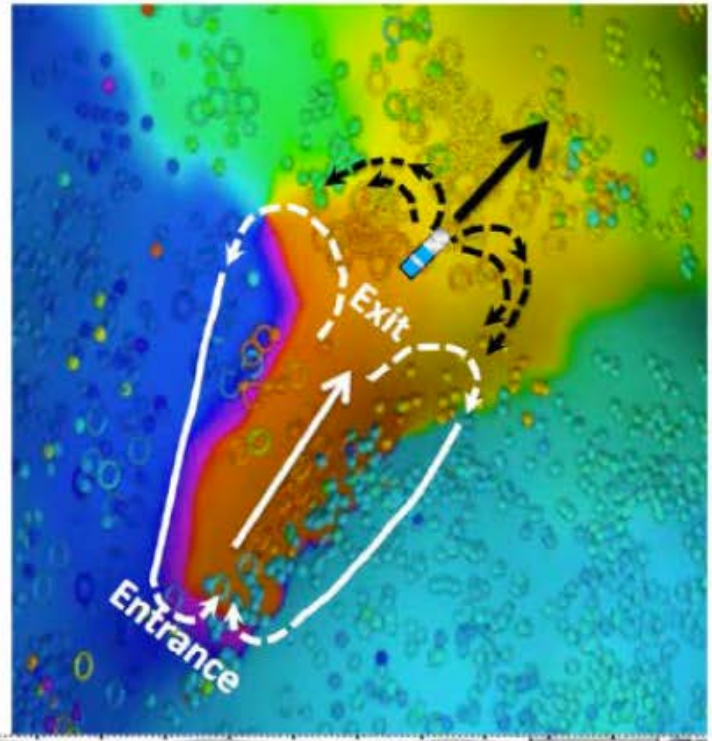
Adjacent Bystander

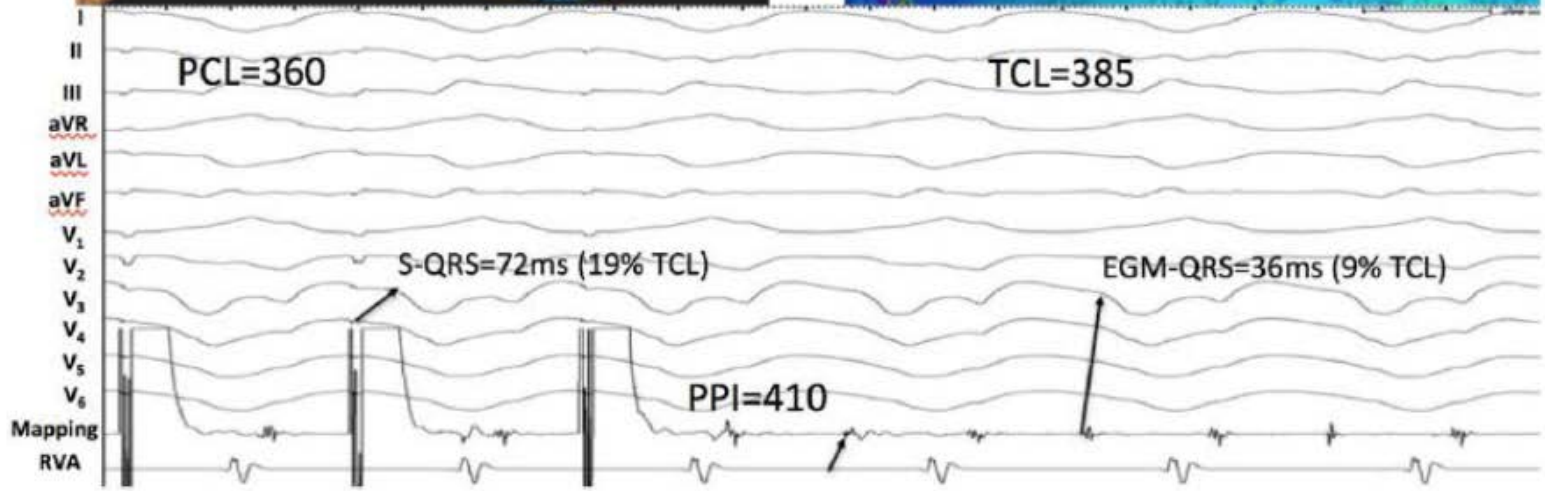
- Concealed
- PPI – TCL >30ms

Stevenson et al. JACC 1997

Entrainment may overestimate circuit size

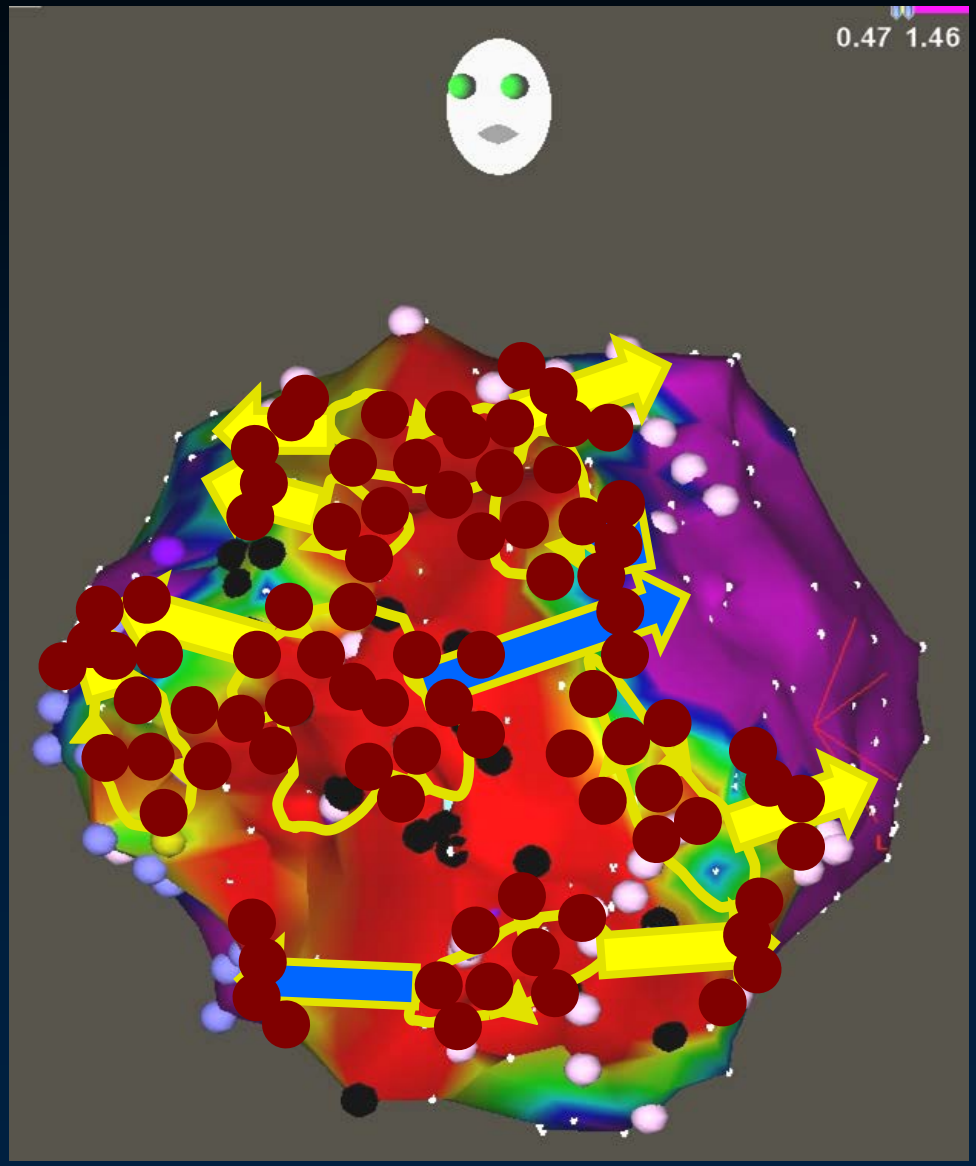






Anter E...Josephson M, et al. High-Resolution Mapping of Post Infarction Reentrant VT. Circulation 2016 134;314-327.

For hemodynamically unstable VT- pacemapping and substrate modification



Sinus Rhythm Clues For Identifying Isthmus

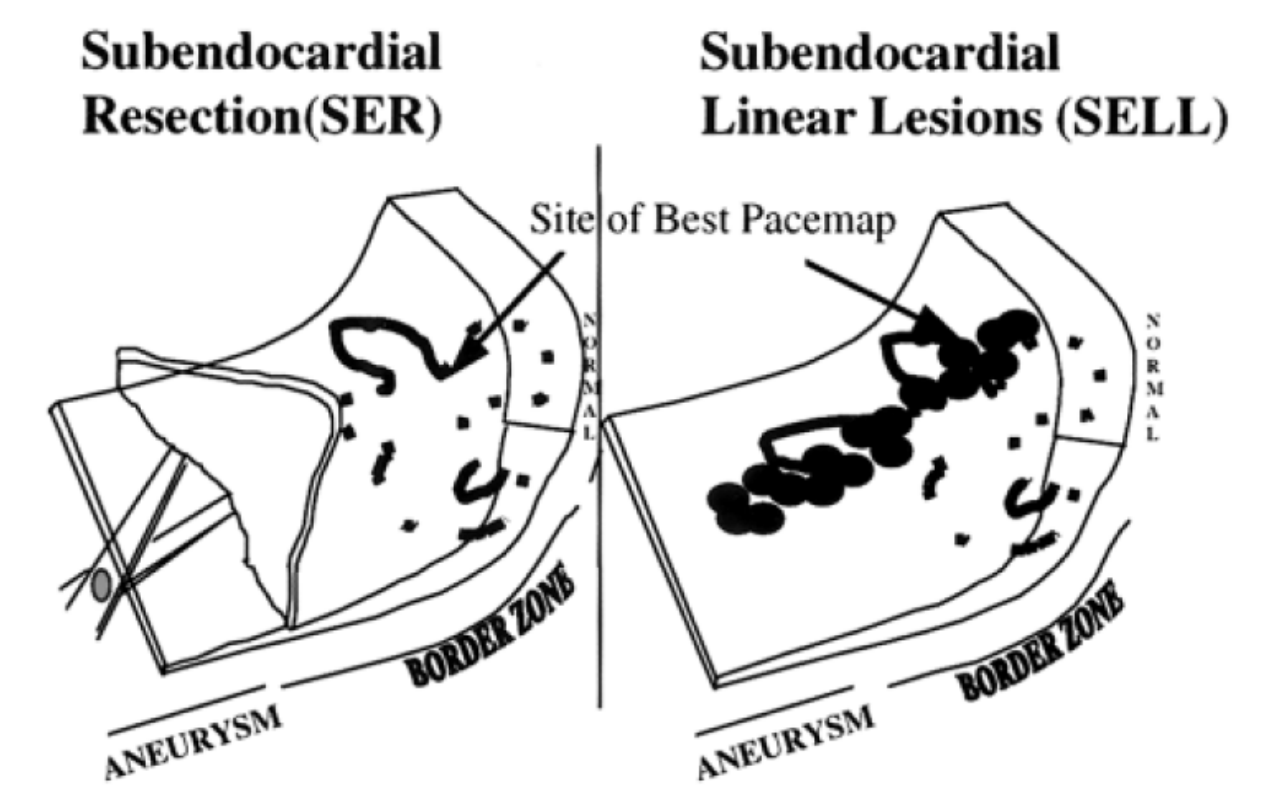
("Dissecting Out The Border Zone And Dense Scar")

- Pacemap match with long stimulus to QRS
- ***Conducting channels*** – Conducting myocardium surrounded by unexcitable myocardium/double potentials/High bipolar voltage surrounded by lower voltage (Soejima et al Circulation 2002, Arenal.. Almendral et al Circulation 2004, Hsia et al Heart Rhythm 2006, de Chillou Circulation 2002)

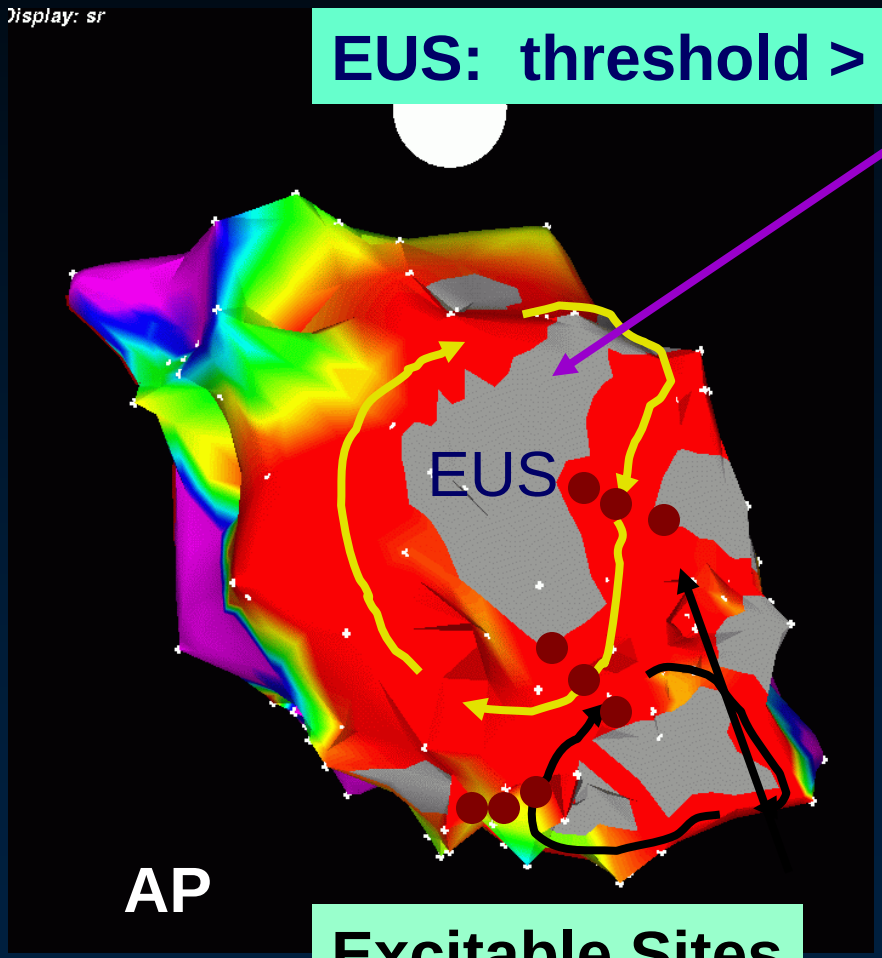
Linear Ablation Lesions for Control of Unmappable Ventricular Tachycardia in Patients With Ischemic and Nonischemic Cardiomyopathy

Francis E. Marchlinski, MD; David J. Callans, MD; Charles D. Gottlieb, MD; Erica Zado, PA-C

Conclusions—Radiofrequency linear endocardial lesions extending from the dense scar to the normal myocardium or anatomic boundary seem effective in controlling unmappable VT. **(*Circulation.* 2000;101:1288-1296.)**



Electrically unexcitable scar (EUS) to identify channel : Unipolar Pacing threshold > 10 mA; pulse width 2 ms



EUS-EUS 16

EUS- annulus 3

EUS- low voltage 1

Courtesy of William Stevenson

Soejima et al Circ 2002;106:1678

Channels Of Conductions in Patients with Tolerated VT - Adjust Color Range of Voltage Map *(High Voltage surrounded by Low Voltage)*

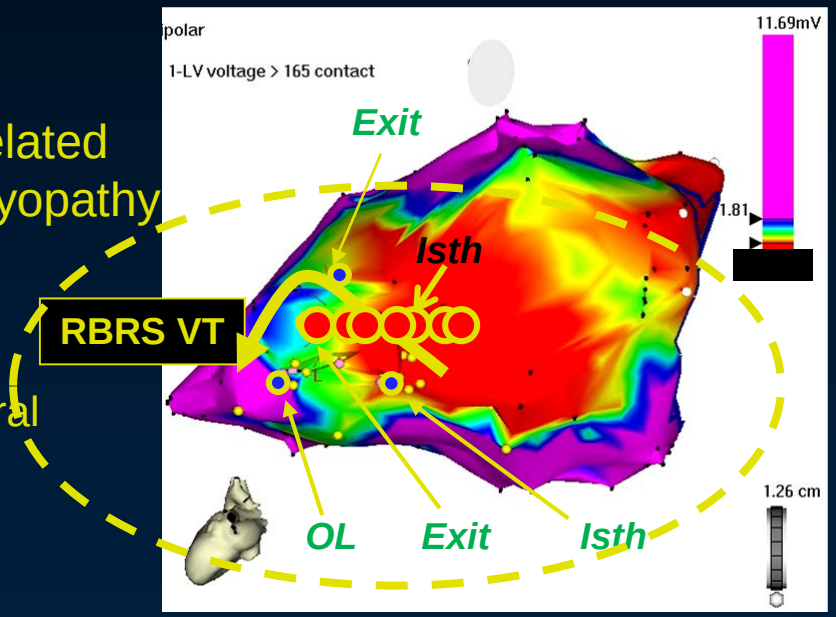
Color Range: 0.5-1.8 mV

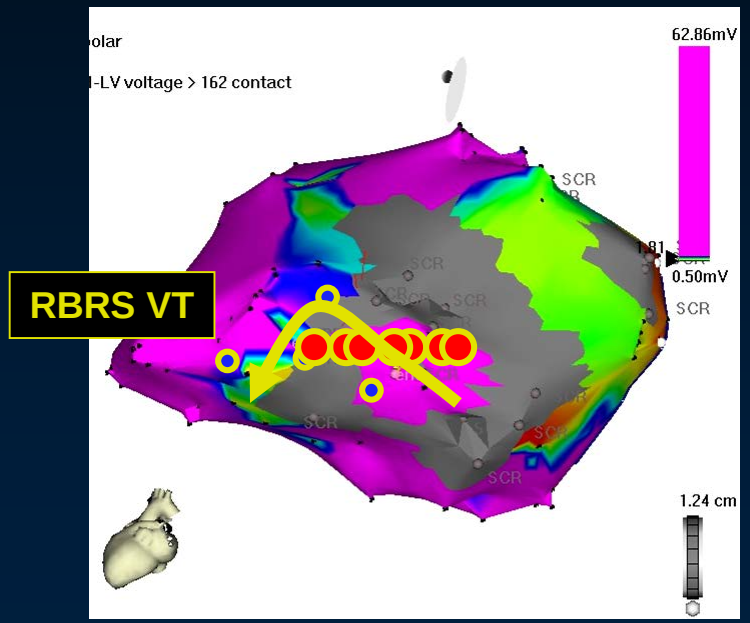
Color Range: 0.1 – 0.4mV

A

Infarct-related Cardiomyopathy

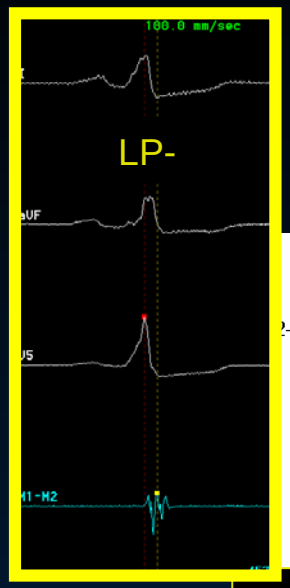
Left lateral

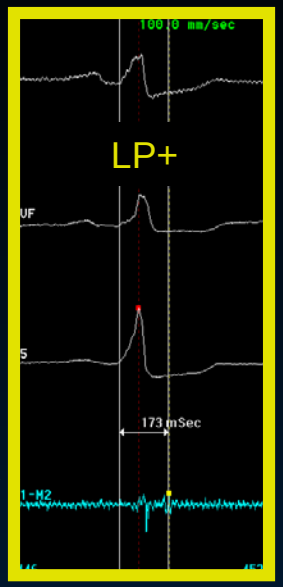




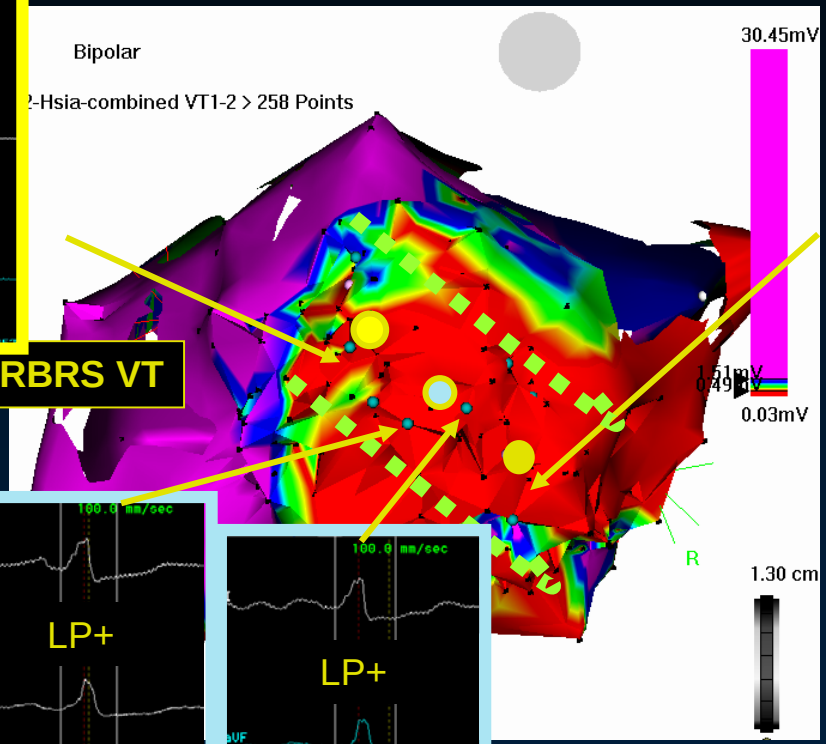
Hsia et al Heart Rhythm 2006

Late Potentials in Baseline Rhythm Near (within1.5 cm) VT Circuit (29 Tolerated VTs)



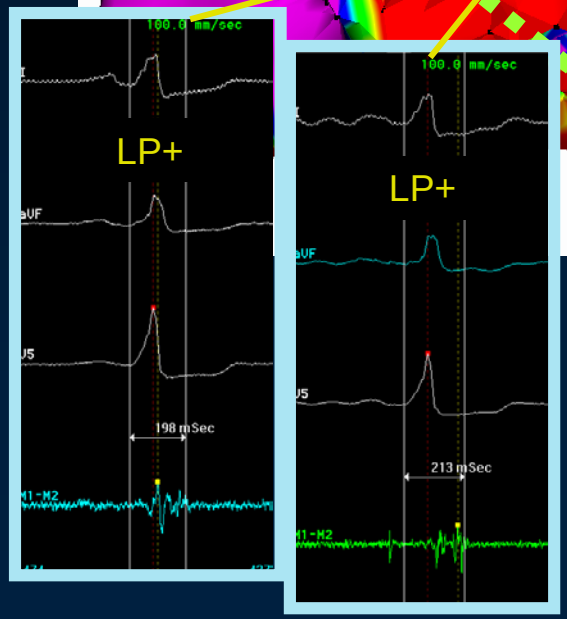


Posterior Lateral



RBRS VT

Inferior-basal Myocardial Infarction

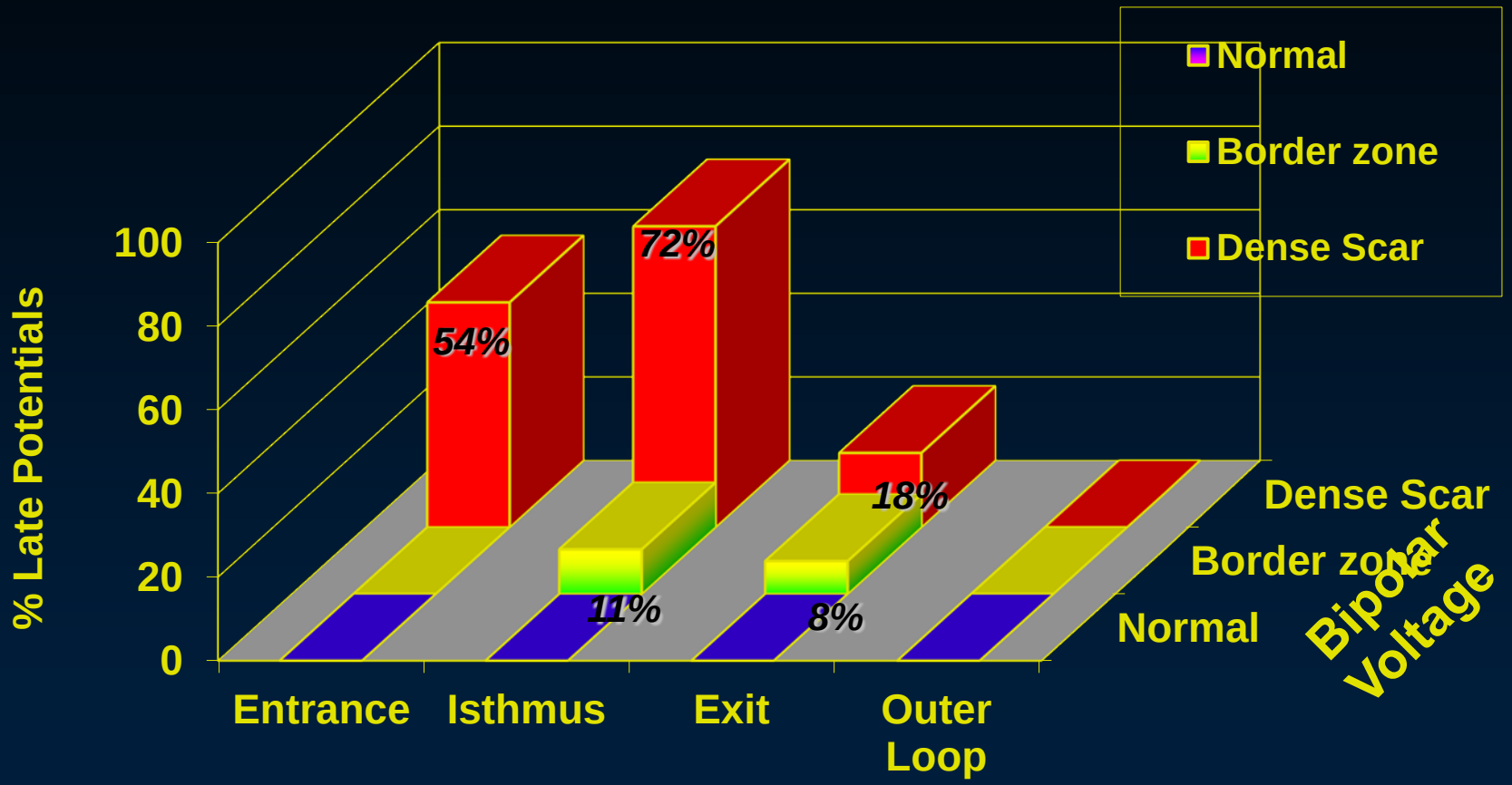


- exit
- isthmus
- entrance

Late electrograms in baseline rhythm usually **present** and **longest** in the **Isthmus** of well tolerated VT

Hsia et al HRS 2006

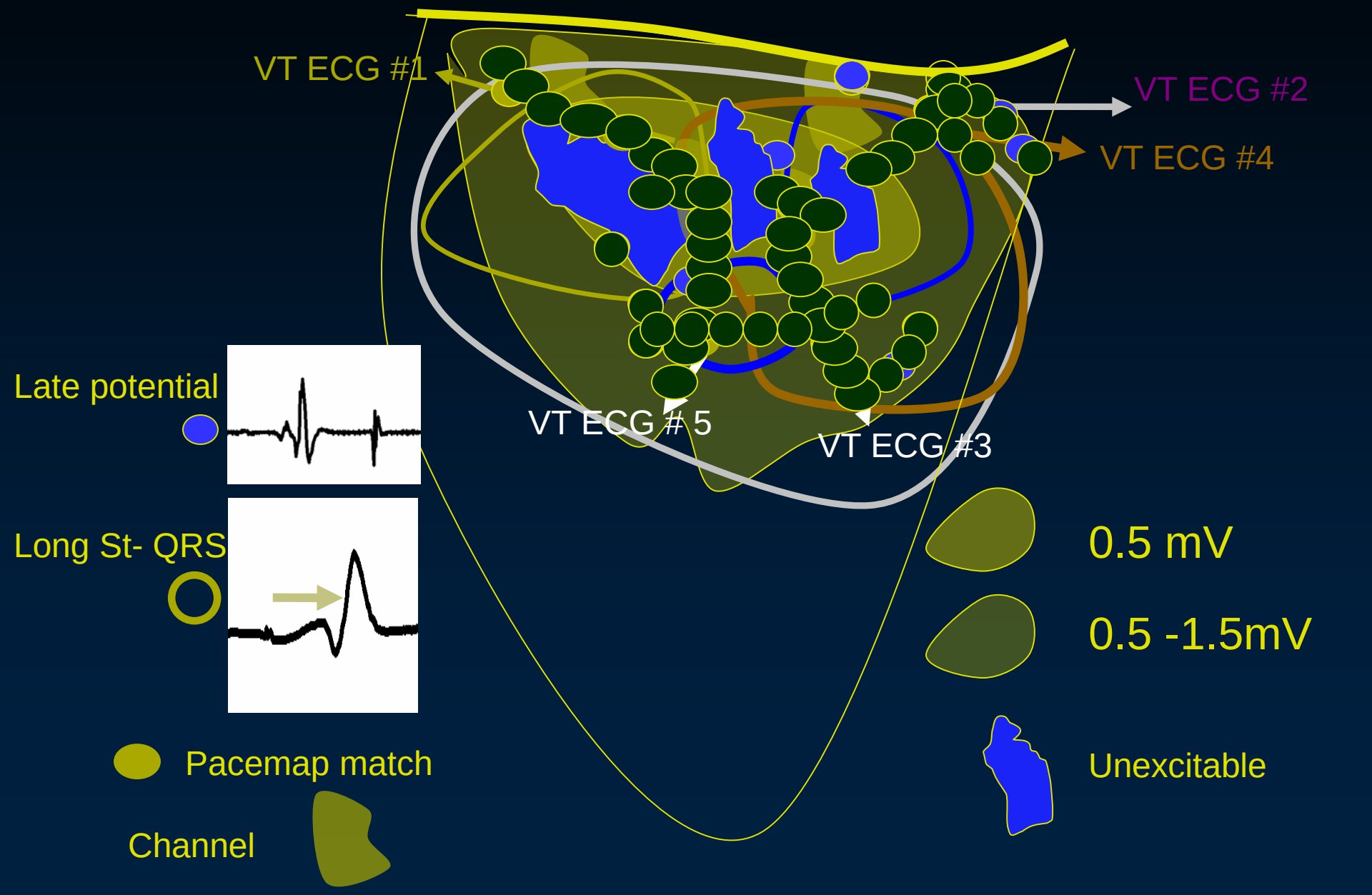
Relationship of Late Potentials in Sinus /Paced Rhythm to Region of VT Circuit (211 sites)



VT Circuit Sites

Hsia et al
HRS 2006

Ablation of Unmappable VT- “Best Approach”?



Sinus Rhythm Clues For Identifying Isthmus

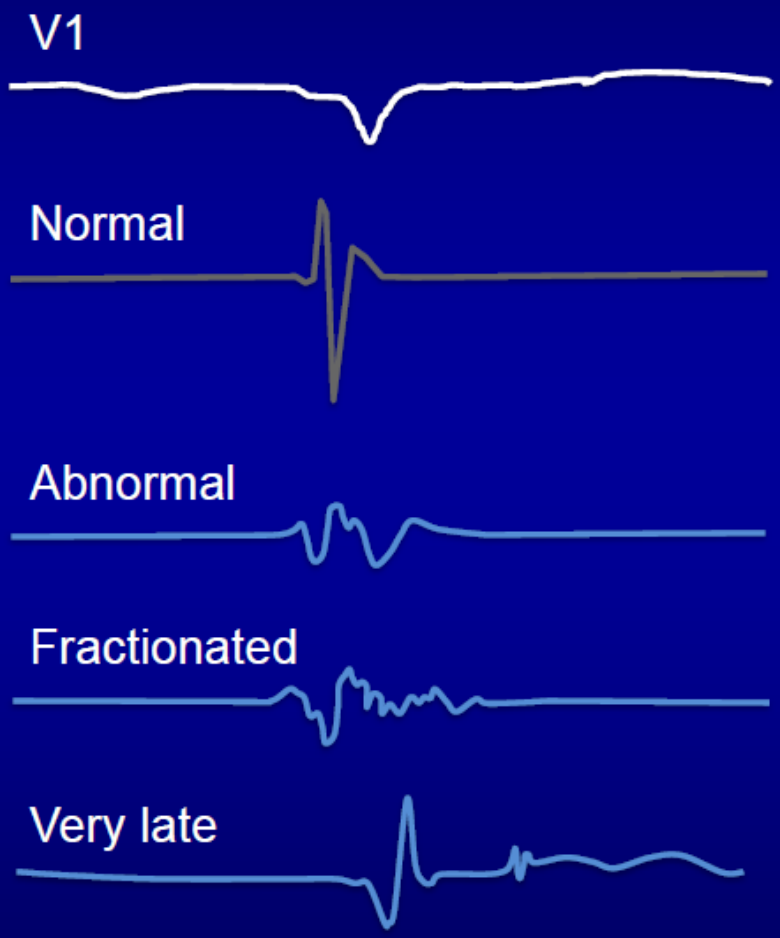
("Dissecting Out The Border Zone And Dense Scar")

- Pacemap match with long stimulus to QRS
- Conducting channels – High bipolar voltage surrounded by lower voltage /unexcitable myocardium and barriers (Soejima et al Circulation 2002, Arenal..,Almendral Circulation 2004, Hsia et al Heart Rhythm 2006, de Chilliou Circulation 2002)
- ***Late potentials*** (Arenal JACC et al 2003)

↓

Sites with slow conduction channels

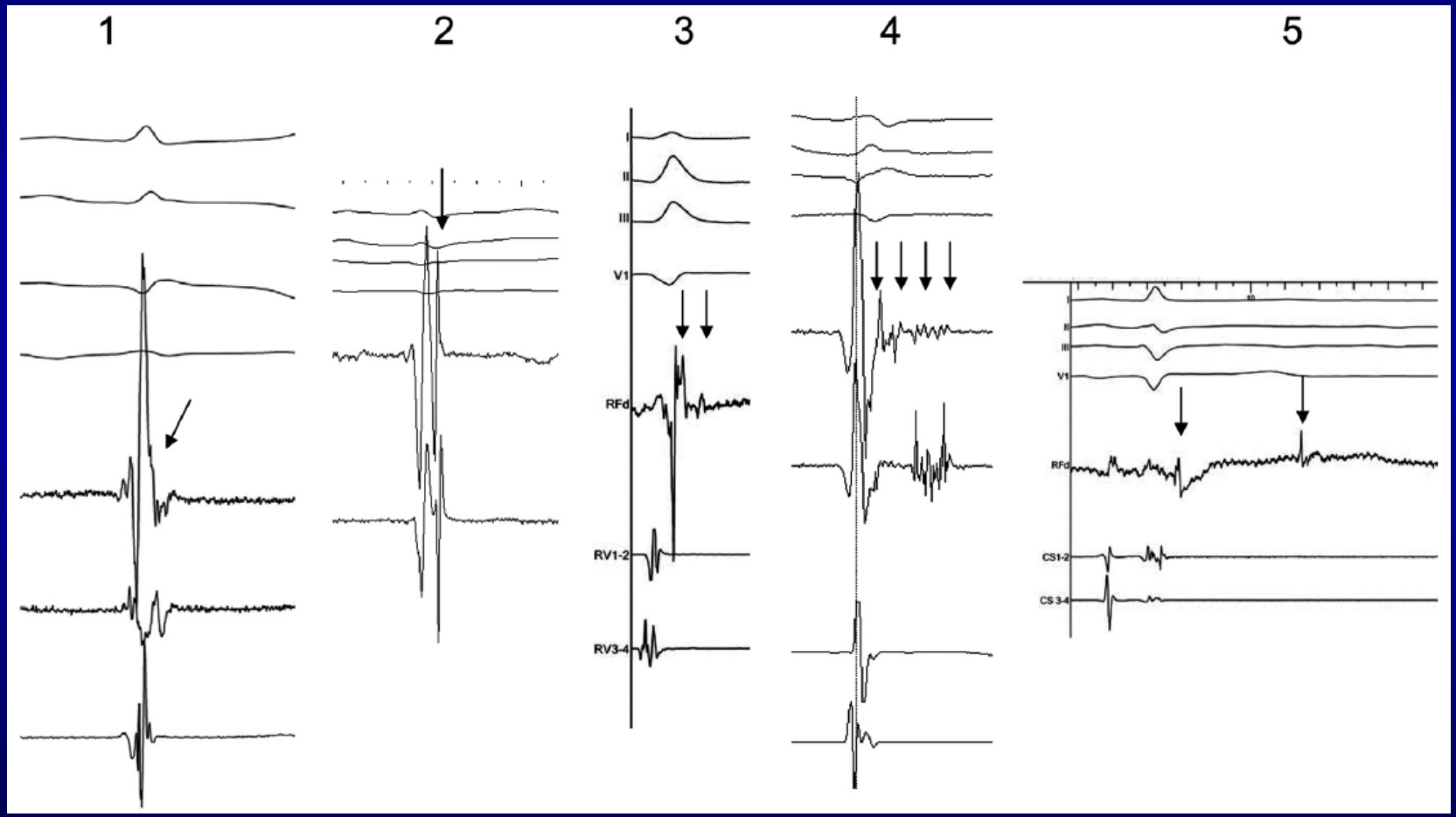
Example of abnormal Electrograms



Cassidy et al. Circulation 1986;73:645-52
Bogun et al. JACC 2006;47:2013-9
Marchlinski et al. Circulation 2000;101:1288

Elimination of Local Abnormal Ventricular Activities

A New End Point for Substrate Modification in Patients With Scar-Related Ventricular Tachycardia

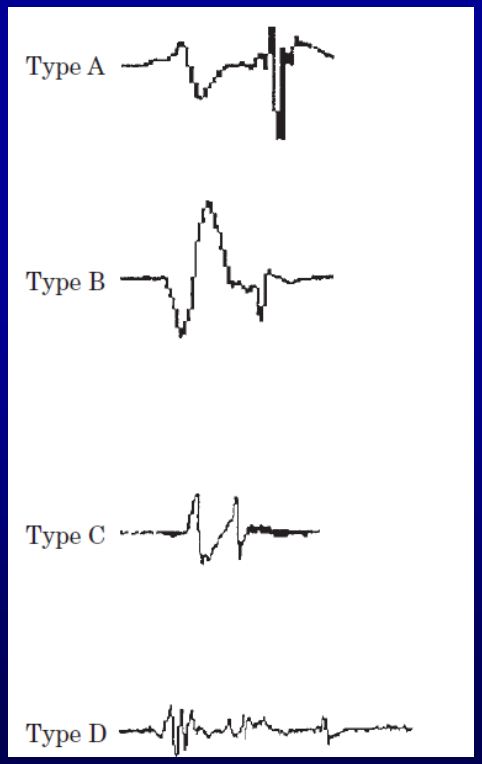


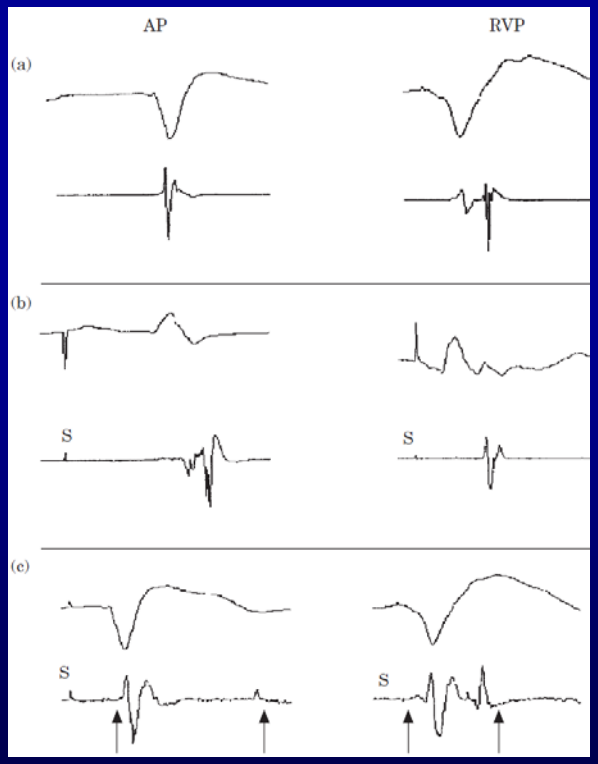
Jaïs P et al. Circulation. 2012;125:2184-2196

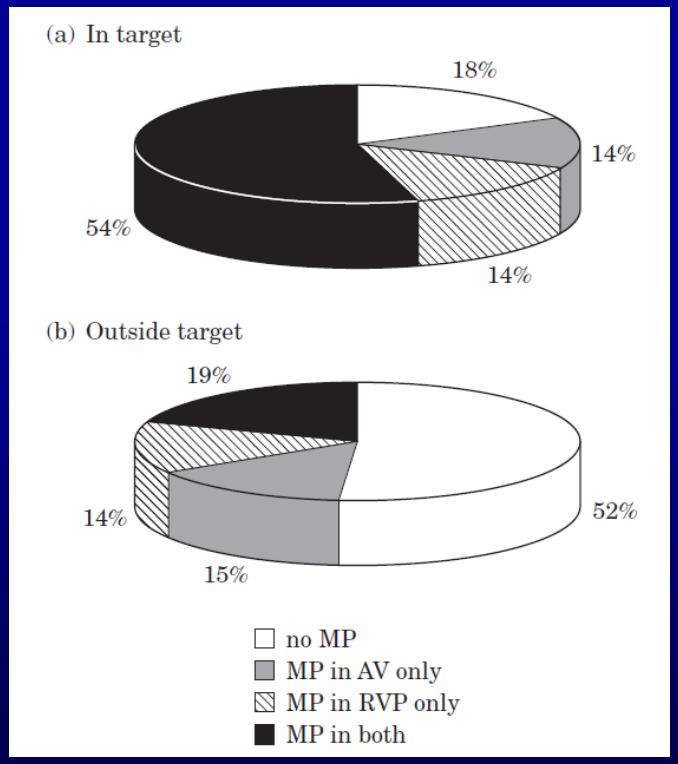
Ventricular mapping during atrial and ventricular pacing

Relationship of multipotential electrograms to ventricular tachycardia reentry circuits after myocardial infarction

C. B. Brunckhorst[1], W. G. Stevenson[1], W. M. Jackman[2], K.-H. Kuck[3], K. Soejima[1], H. Nakagawa[2], R. Cappato[3] and S. A. Ben-Haim[4]







Eur Heart J, 2002; 23: 1131–1138

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EDITORIAL COMMENT

A Moving Target for Catheter Ablation of Ventricular Tachycardia

Ablation of Scar or Arrhythmia?*

Roderick Tung, MD,† Hans Kottkamp, MD‡

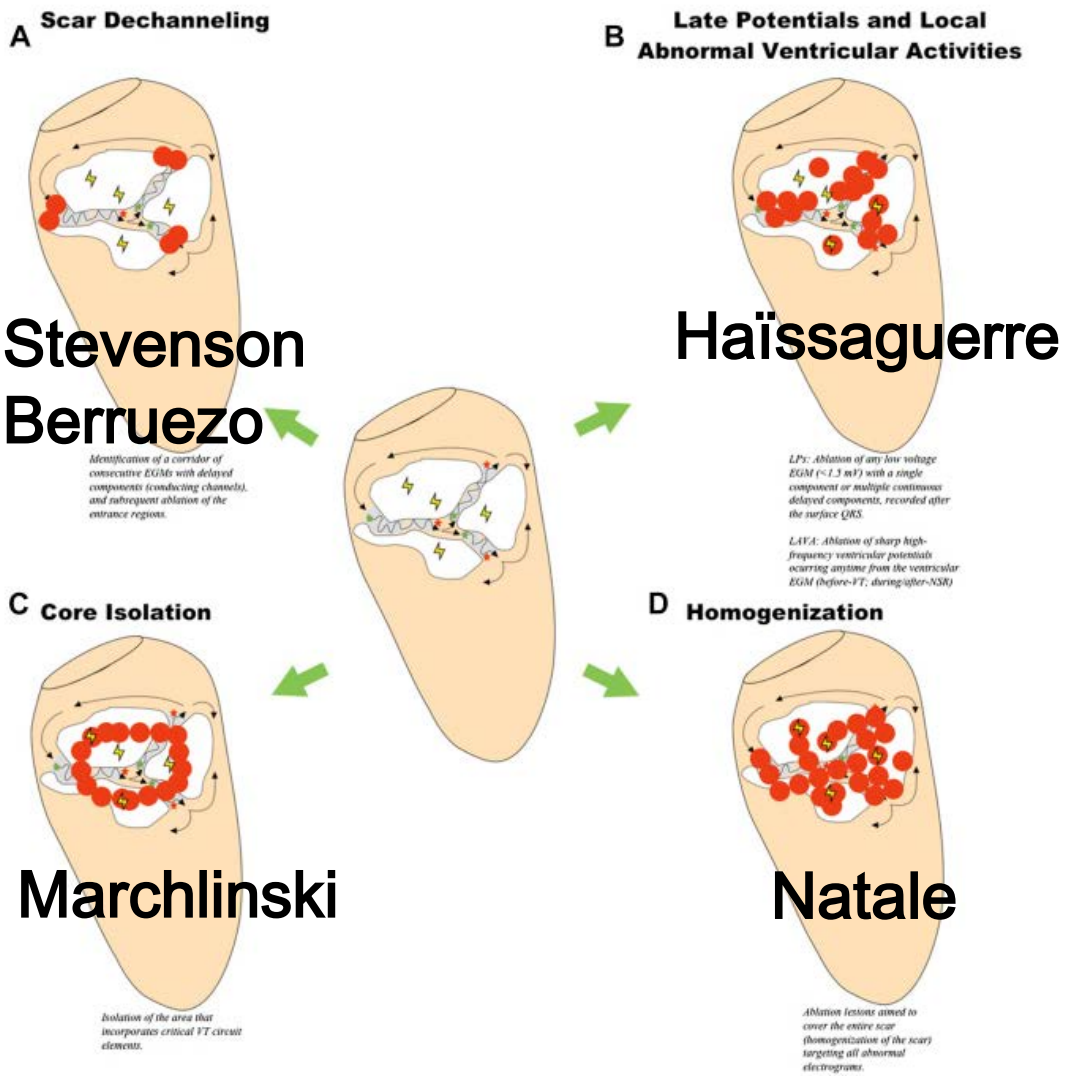

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Fig. 4. Strategies for substrate-based ablation. Areas between channels often have electrical activity giving rise to VT substrates (*thunderbolts*); thus, elimination of scar related potentials is a relevant ablation goal and is the basis of different substrate-based ablation strategies. (*A*) Scar dechanneling, (*B*) ablation of LPs and LAVAs, (*C*) CI (core isolation), and (*D*) homogenization of the scar. NSR, normal sinus rhythm.

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Europace (2017) 00, 1–12
doi:10.1093/europace/eux109

CLINICAL RESEARCH

Long-term outcomes of different ablation strategies for ventricular tachycardia in patients with structural heart disease: systematic review and meta-analysis

David F. Briceño[1], Jorge Romero[1], Pedro A. Villablanca[1], Alejandra Londoño[1], Juan C. Diaz[1], Ilir Maraj[1], Syeda Atiqa Batul[1], Nidhi Madan[1], Jignesh Patel[1], Anand Jagannath[1], Sanghamitra Mohanty[2], Prasant Mohanty[2], Carola Gianni[2], Domenico Della Rocca[2], Ahlam Sabri[1], Soo G. Kim[1], Andrea Natale[2,3,4,5,6,7,8,9], and Luigi Di Biase[1,2,3,9]*

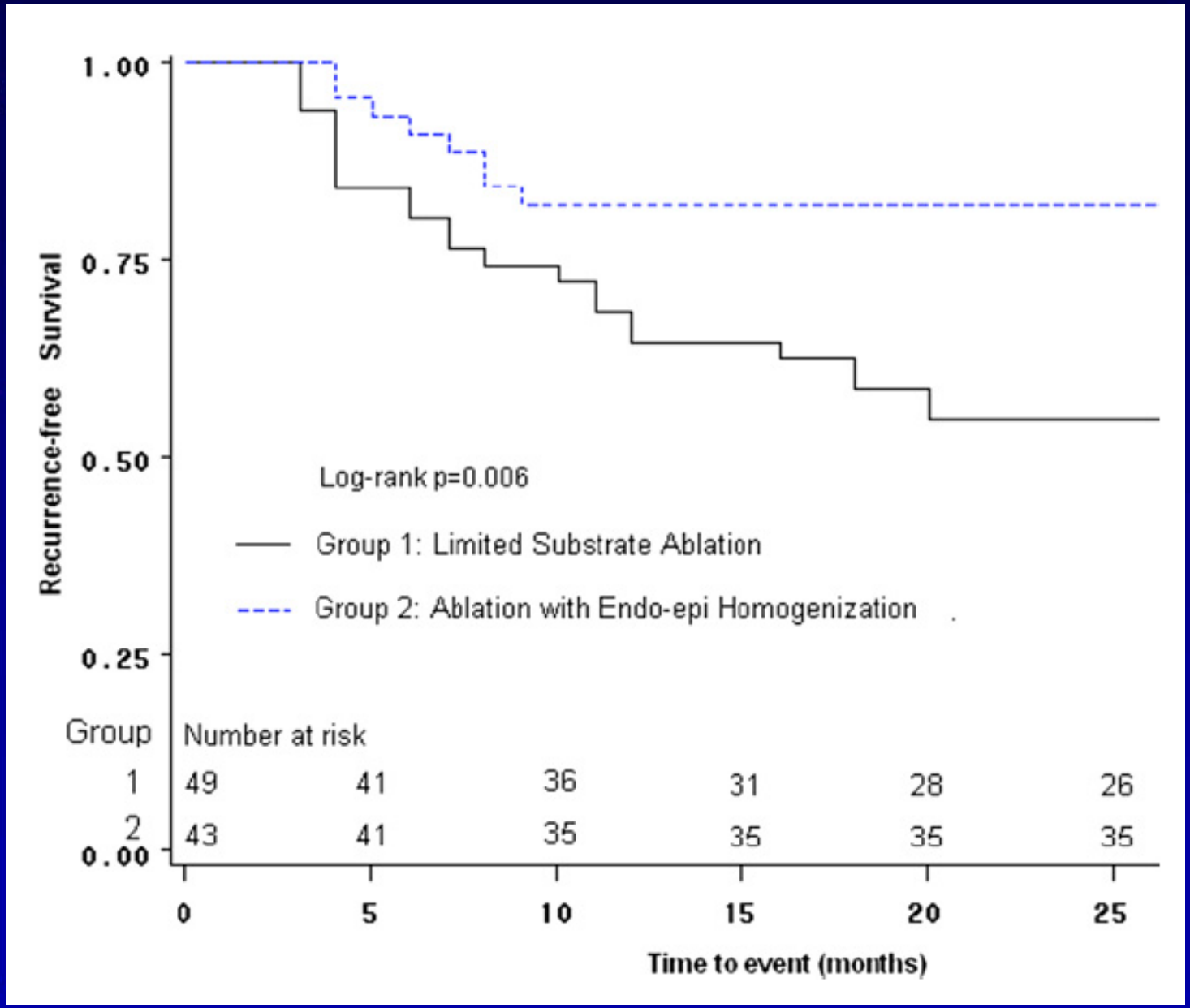
Briceno, Romero, Di Biase. Europace 2017

Endo-Epicardial Homogenization of the Scar Versus Limited Substrate Ablation for the Treatment of Electrical Storms in Patients With Ischemic Cardiomyopathy

Luigi Di Biase, MD, PHD,*†‡ Pasquale Santangeli, MD,*‡ David J. Burkhardt, MD,*§ Rong Bai, MD,* Prasant Mohanty, MBBS, MPH,* Corrado Carbucicchio, MD,‖ Antonio Dello Russo, MD,‖ Michela Casella, MD,‖ Sanghamitra Mohanty, MD,* Agnes Pump, MD,*¶ Richard Hongo, MD,§ Salwa Beheiry, RN,§ Gemma Pelargonio, MD,# Pietro Santarelli, MD,# Martina Zucchetti, MD,‖ Rodney Horton, MD,* Javier E. Sanchez, MD,* Claude S. Elayi, MD,** Dhanunjay Lakkireddy, MD,†† Claudio Tondo, MD,‖ Andrea Natale, MD*†§

Austin, Texas; Foggia, Milan, and Rome, Italy; San Francisco, California; Pecs, Hungary; Lexington, Kentucky; and Kansas City, Kansas

Di Biase, Natale at al J Am Coll Cardiol 2012



Di Biase, Natale at al J Am Coll Cardiol 2012

Goal of this ablation strategy:

- covering entire scar with ablation lesions targeting abnormal electrograms (i.e., abolition of all abnormal potentials)

- In the first 10 patients, pacing was performed at high output (up to 20 mA with a pulse duration of 10ms) from within the ablation area, but capture was not seen

Table 3 Procedural end points of the different substrate modification strategies

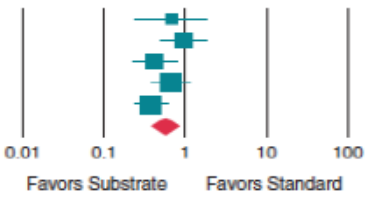
Study	Year	Substrate technique	Procedural end point
Jais[5]	2012	LAVA	Elimination of all sharp high-frequency ventricular potentials, occurring anytime during or after the far-field ventricular electrogram in sinus rhythm or before the far-field ventricular electrogram during VT
Vergara[7]	2012	Late potentials	Complete abolition of all late potentials
Tilz[13]	2014	Substrate isolation	Isolation of the entire substrate and defined as (i) lack of fractionated, double or late potentials inside the encircled area 20 min post-ablation, (ii) non-capture of the LV during pacing with maximal output at multiple sites within the encircled area, and (iii) after a maximum of 40 RF applications
Berruezo[9]	2015	Scar dechanneling	Elimination of all identified CCs at the CC entrance during sinus rhythm
Tzou[12]	2015	Core isolation	Failure to capture the ventricle with pacing from inside the lesion set (exit block) that conforms the isolated core
Jamil-Copley[14]	2015	RMCC	Ablation overlapping all RMCCs
Gokoglan[15]	2016	Scar homogenization	Empirical elimination of all abnormal electrograms throughout the entire scar

Briceno, Romero, Di Biase. Europace 2017

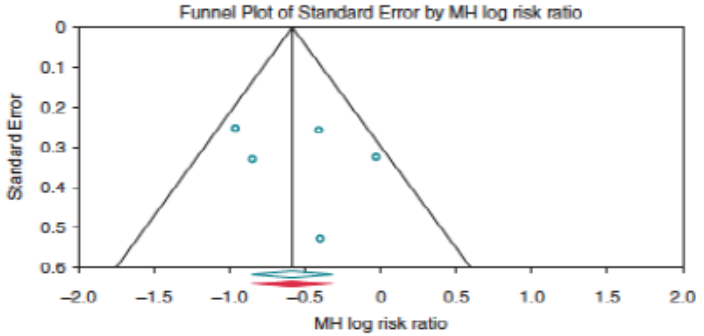
A

Ventricular Arrhythmia Recurrence / All-Cause Mortality

Study name	MH risk ratio	Lower limit	Upper limit	Events / Total: Substrate	Events / Total: Standard	Relative weight
Arenal	0.67	0.24	1.87	6/18	3/6	9.61
Volkmer	0.97	0.51	1.83	11/25	10/22	19.55
Di Biaso 2012	0.43	0.22	0.82	9/43	24/49	19.13
Makimoto	0.66	0.40	1.09	17/50	18/35	25.66
Di Biase 2015	0.38	0.23	0.63	14/58	38/60	26.06
	0.57	0.40	0.81	57/194	93/172	



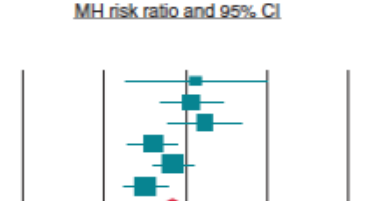
Random effects models
Heterogeneity: Tau2=0.06; Chi2=6.48; df=4; P=0.17; I2=38.3%
Test for overall effect Z=–3.13 (p=0.00)



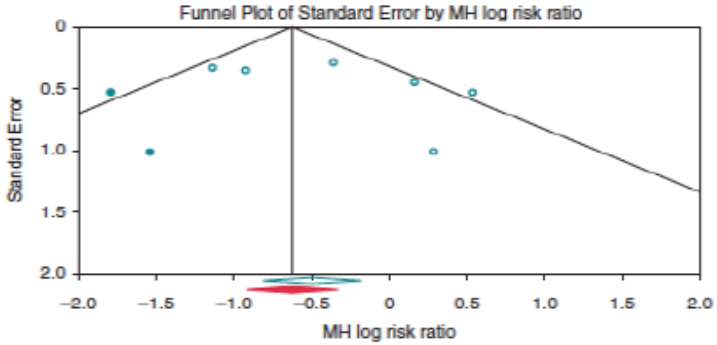
B

Ventricular Arrhythmia Recurrence

Study name	MH risk ratio	Lower limit	Upper limit	Events / Total: Substrate	Events / Total: Standard	Relative weight
Arenal	1.33	0.18	9.72	4/18	1/6	5.74
Volkmer	1.17	0.48	2.86	8/25	6/22	16.44
Ventura	1.71	0.60	4.86	6/14	4/16	14.01
Di Biase 2012	0.40	0.20	0.79	8/43	23/49	20.17
Makimoto	0.70	0.40	1.24	15/52	15/35	22.71
Di Biase 2015	0.32	0.17	0.62	9/58	20/60	20.04
	0.68	0.40	1.15	50/208	78/188	



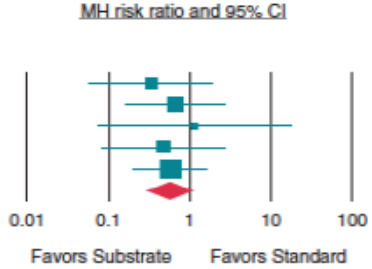
Random effects models
Heterogeneity: Tau2=0.23; Chi2=12; df=5; P=0.04; I2=58.2%
Test for overall effect Z=–1.44 (p=0.15)



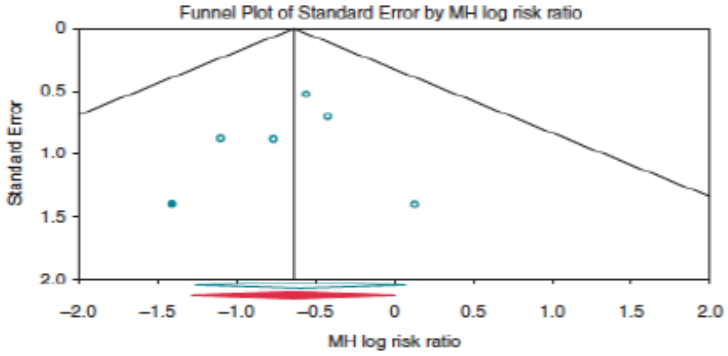
C

All-Cause Mortality

Study name	MH risk ratio	Lower limit	Upper limit	Events / Total: Substrate	Events / Total: Standard	Relative weight
Arenal	0.33	0.06	1.88	2/18	2/6	14.59
Volkmer	0.66	0.17	2.63	3/25	4/22	20.69
Di Biase 2012	1.14	0.07	17.67	1/43	1/49	4.55
Makimoto	0.47	0.08	2.65	2/50	3/35	17.16
Di Biase 2015	0.57	0.20	1.61	5/58	9/60	43.02
	0.56	0.29	1.09	13/194	19/172	



Fixed effects models
Heterogeneity: Tau2=0.00; Chi2=0.7; df=4; P=0.95; I2=0%
Test for overall effect Z=–1.69 (p=0.09)



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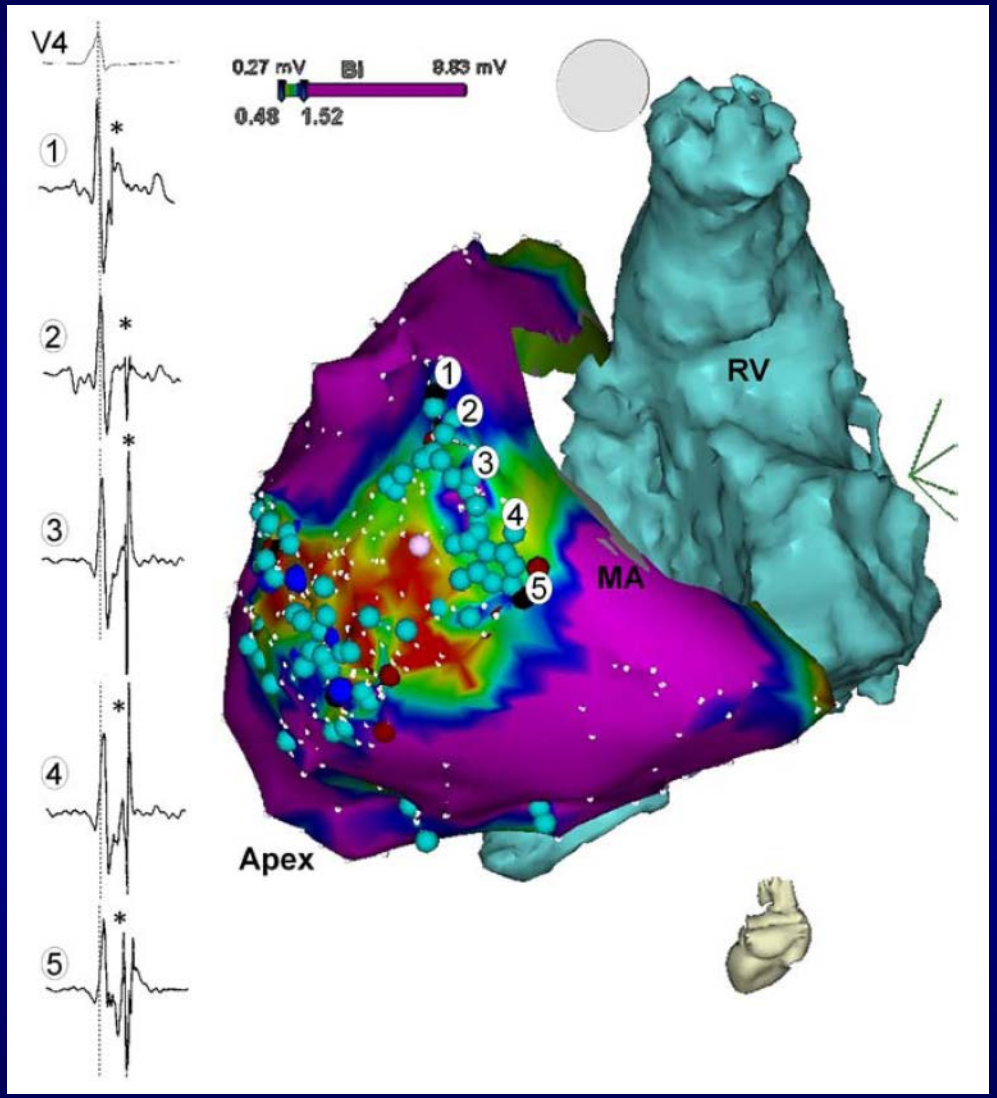
Original Article

Scar Dechanneling

New Method for Scar-Related Left Ventricular Tachycardia Substrate Ablation

Antonio Berruezo, MD, PhD; Juan Fernández-Armenta, MD, PhD; David Andreu, MSc, PhD; Diego Penela, MD; Csaba Herczku, MD; Reinder Evertz, MD; Laura Cipolletta, MD; Juan Acosta, MD; Roger Borràs, MSc; Elena Arbelo, MD, PhD; Jose María Tolosana, MD, PhD; Josep Brugada, MD, PhD; Lluis Mont, MD, PhD

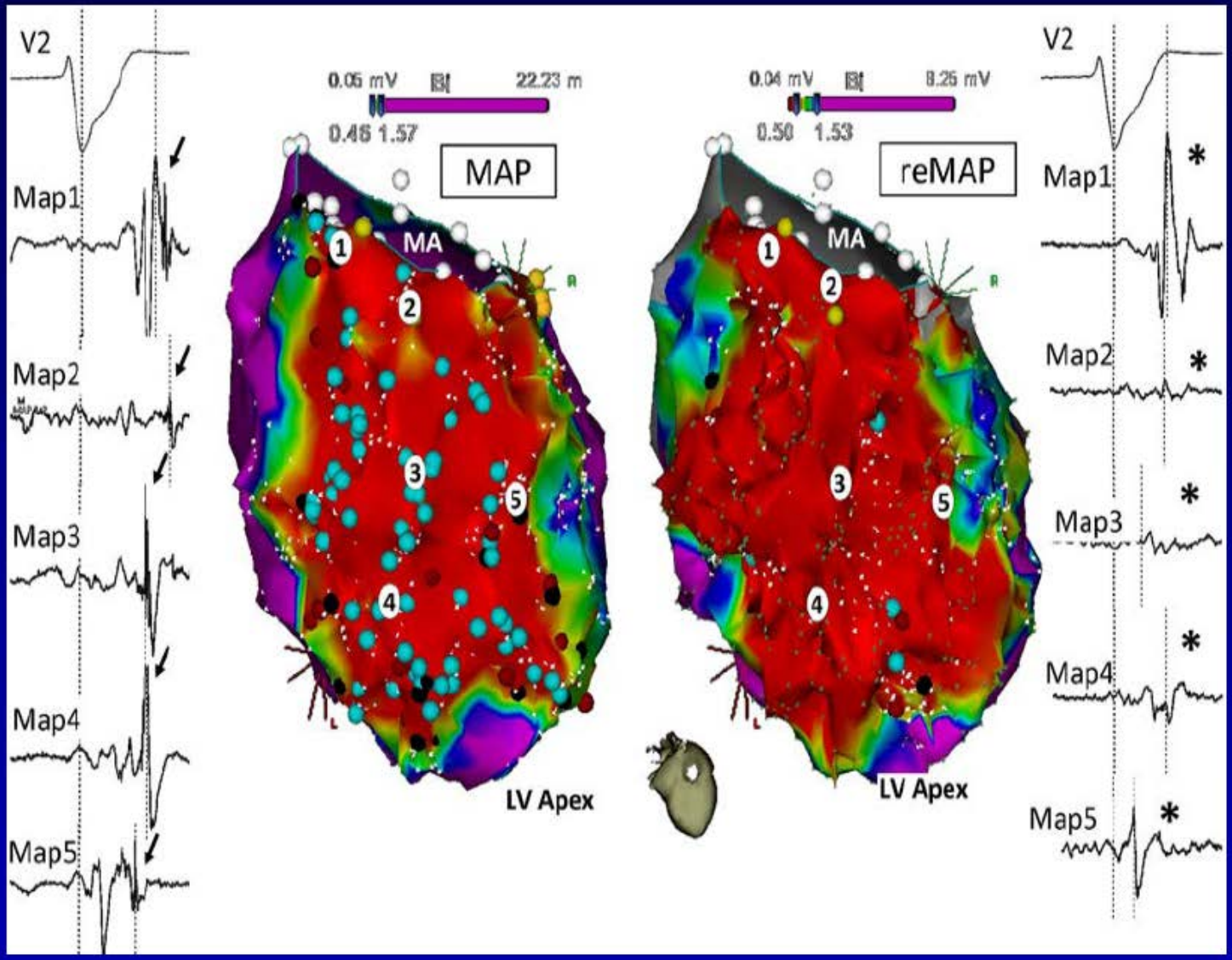
Berruzo et al. Circ Arrhythm Electrophysiol . 2015;8:326-336.



- E-DCs (electrograms with delayed components)
- Entrance

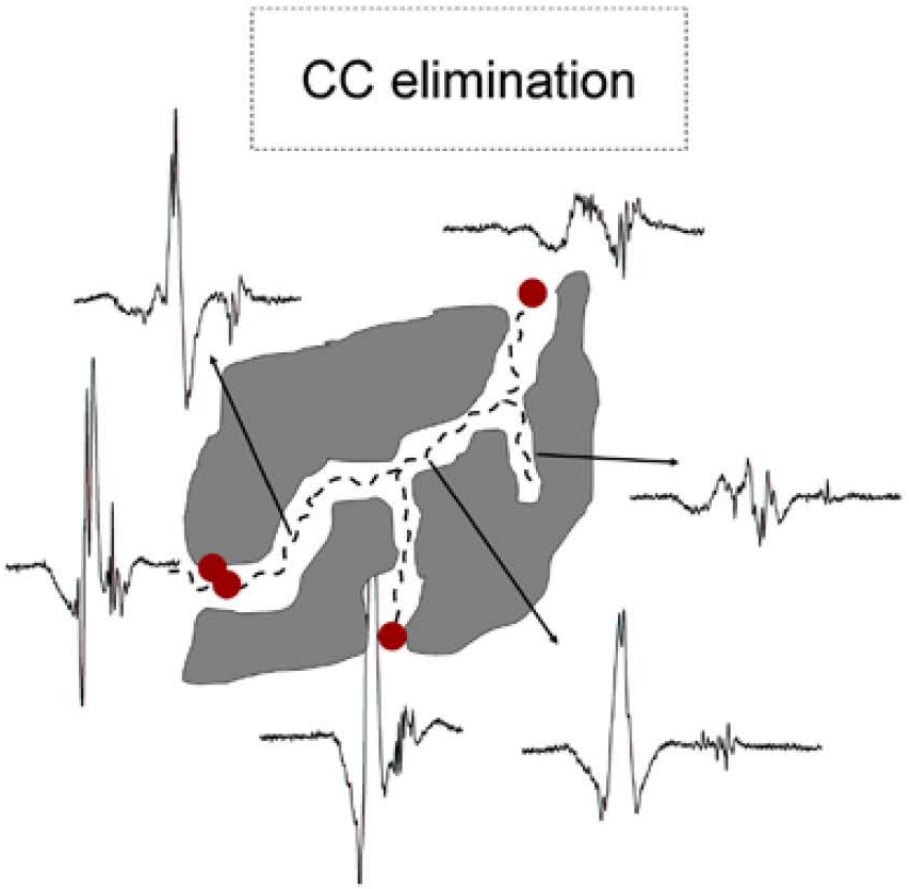
  E-DC with the Shortest delay between the far-field component of healthy/BZ muscle and local component (delayed, high frequency, usually fractionated and low voltage)

Berruzo et al. Circ Arrhythmia Electrophysiol 2015; 8:326-336



Berruzo et al. Circ Arrhythm Electrophysiol . 2015;8:326-336

Steps	VT Ablation Procedure
1	Substrate mapping CC entrance identification
2	CC elimination
3	Re-mapping Residual CC ablation
4	Inducibility Residual VT ablation



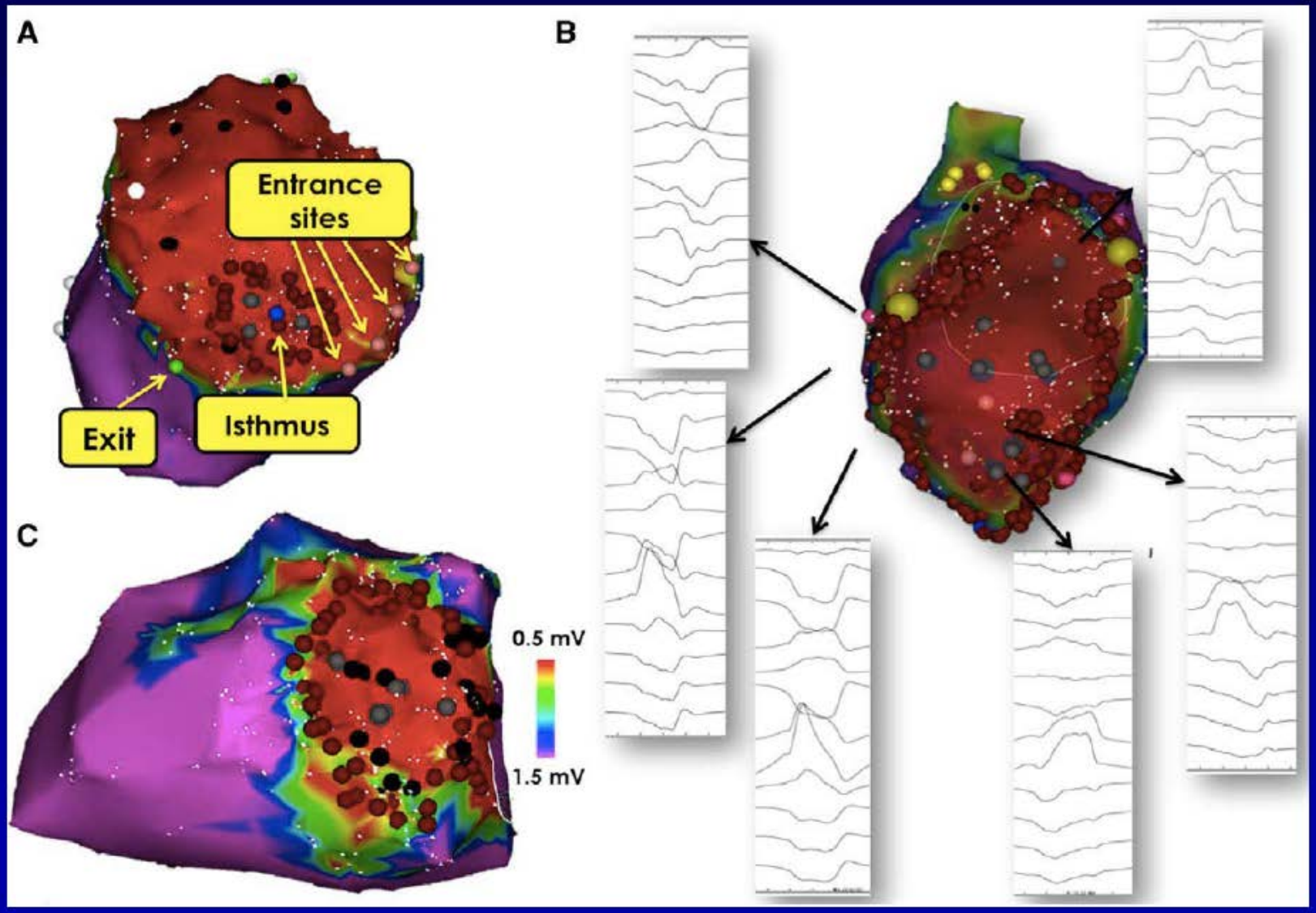
Berruzo et al. Circ Arrhythm Electrophysiol . 2015;8:326-336

Original Article

Core Isolation of Critical Arrhythmia Elements for Treatment of Multiple Scar-Based Ventricular Tachycardias

Wendy S. Tzou, MD*; David S. Frankel, MD*; Timothy Hegeman, DO; Gregory E. Supple, MD; Fermin C. Garcia, MD; Pasquale Santangeli, MD; David F. Katz, MD; William H. Sauer, MD; Francis E. Marchlinski, MD

Tzou et al.Circ Arrhythm Electrophysiol. 2015;8:353-361



Tzou et al.Circ Arrhythm Electrophysiol. 2015;8:353-361

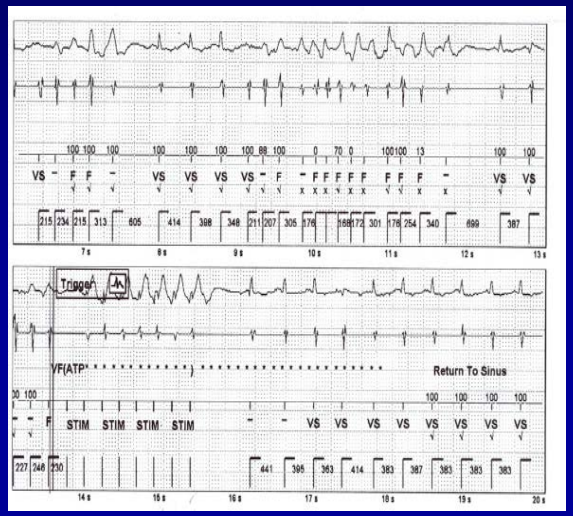
- CI was attempted by surrounding the putative isthmus or entrance and early exit sites, which were identified based on pacemapping or entrainment mapping.
- Successful CI was defined by failure to capture the ventricle from multiple sites
- Additional, reinforcing lesions were placed within the isolated area targeting sites of LAVA and LP noted in SR.
- Ventricular programmed electric stimulation was repeated after CI

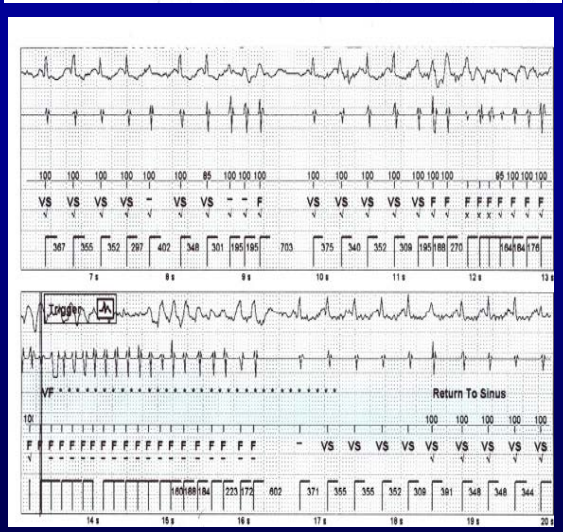
Tzou et al.Circ Arrhythm Electrophysiol. 2015;8:353-361

- If any VT was still inducible, other regions within scar but potentially outside of the isolated region were targeted as needed, based on LP and favorable pacemap.
- Epicardial mapping and ablation were performed because of continued inducibility of VT; prior failed endocardial ablation; epicardial 12-lead ECG VT characteristics; or lack of abnormal endocardial substrate.
- Epicardial CI was performed and program stimulation repeated (failure to capture) + (LAVA and LP).
- Efforts to achieve CI and VT non-ducibility continued as long as patient safety and tolerance.

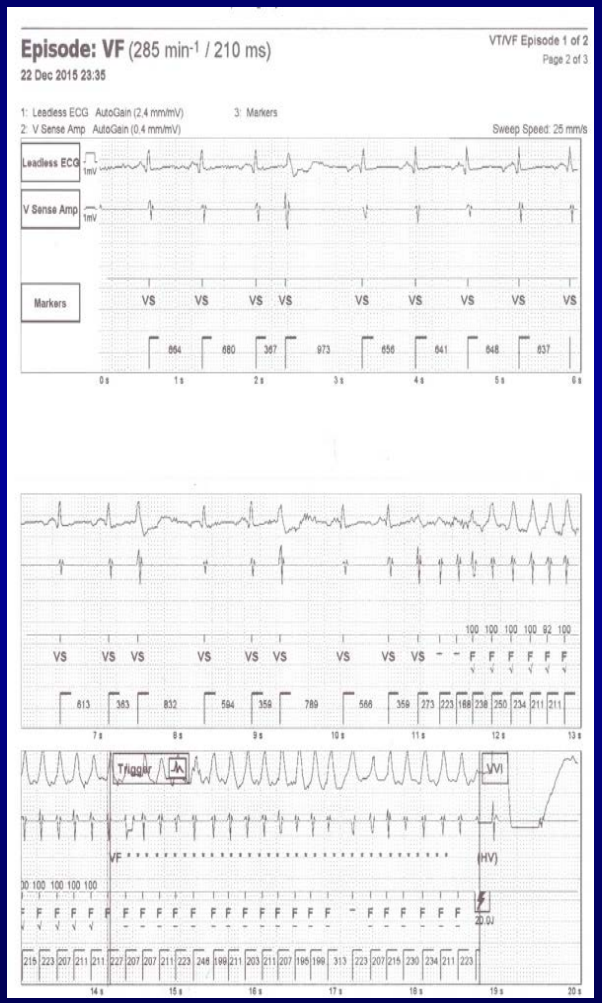
Tzou et al.Circ Arrhythm Electrophysiol. 2015;8:353-361

Recurrent VT/VF episodes



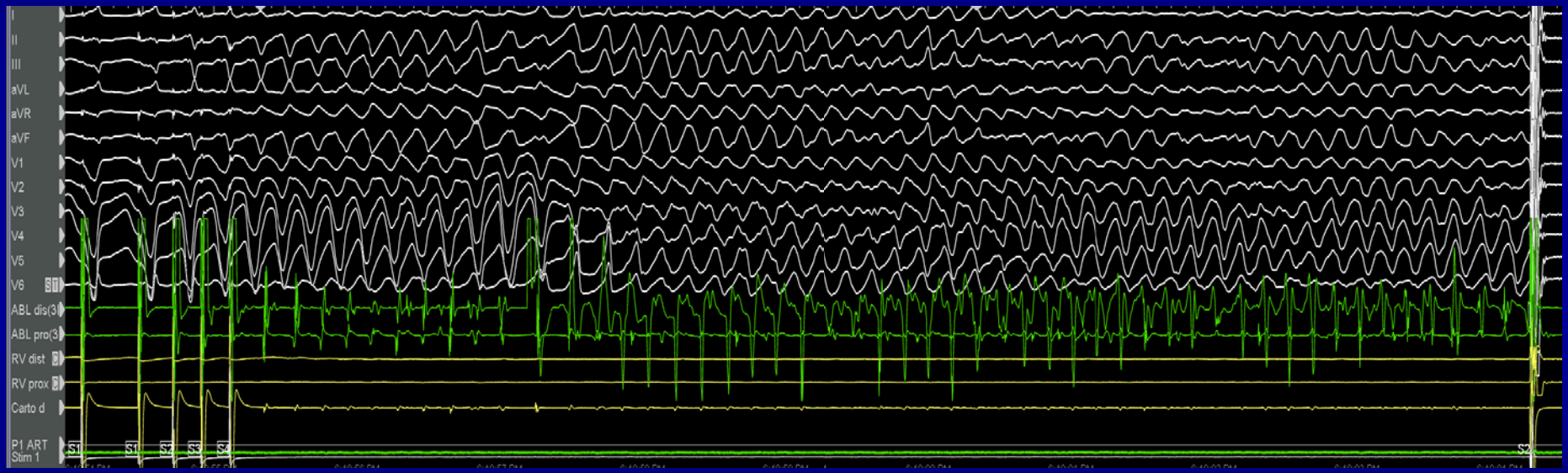


2015-10-04



2015-12-22

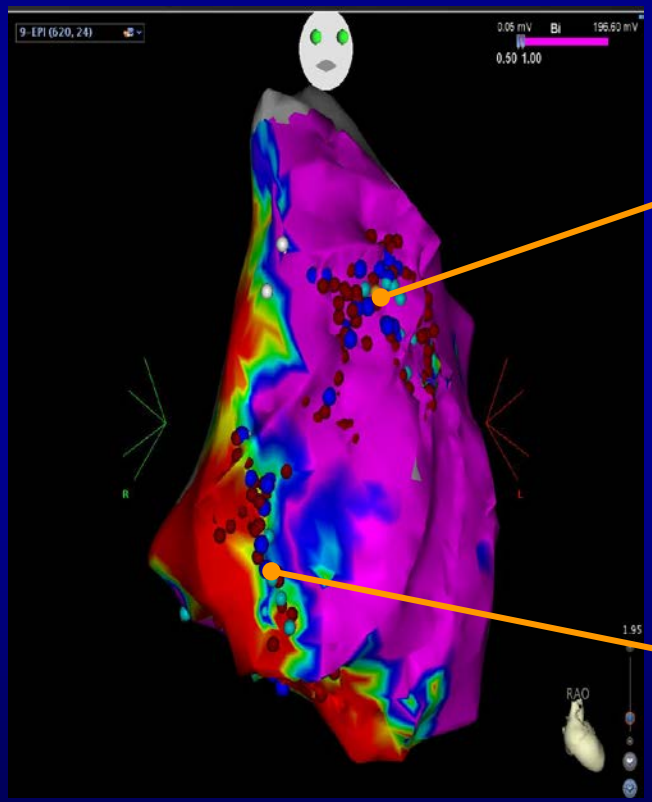
VT conversion to VF

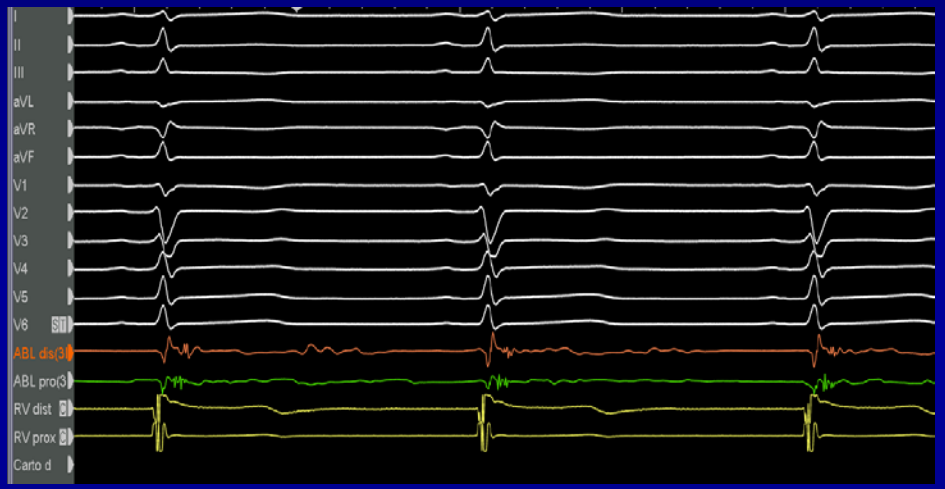


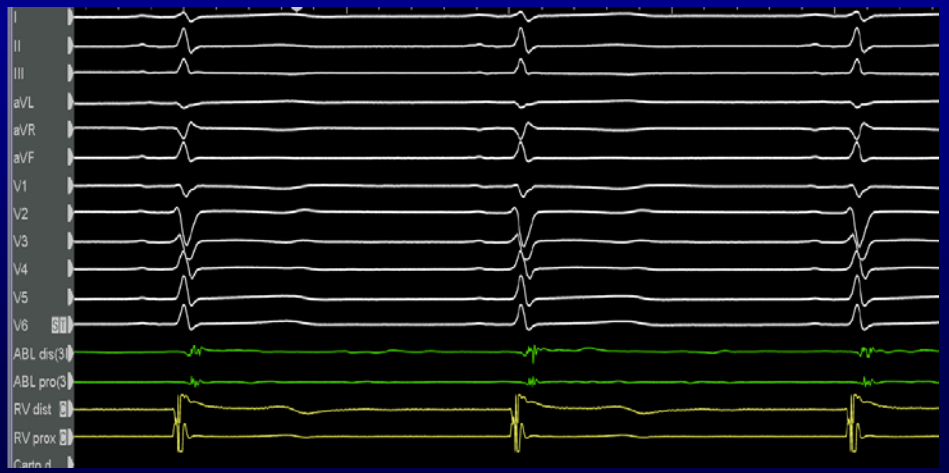
Termination with cardioversion (200J)

Epicardial local signals

- Late Potentials in RV inferolateral and anterior wall (dark blue dot)

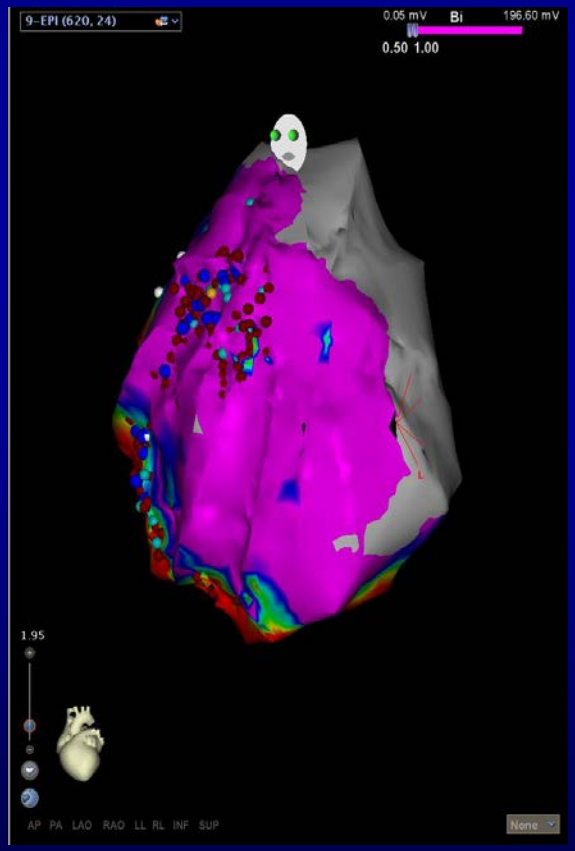


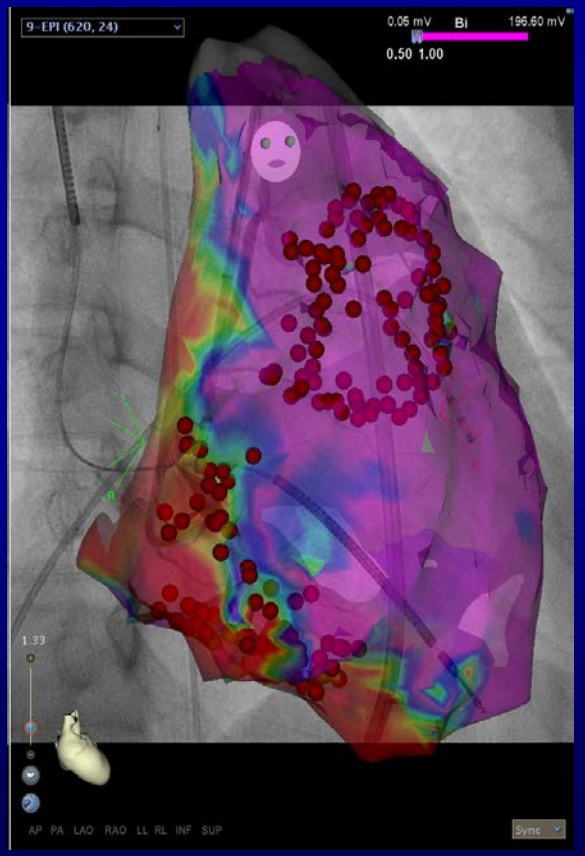


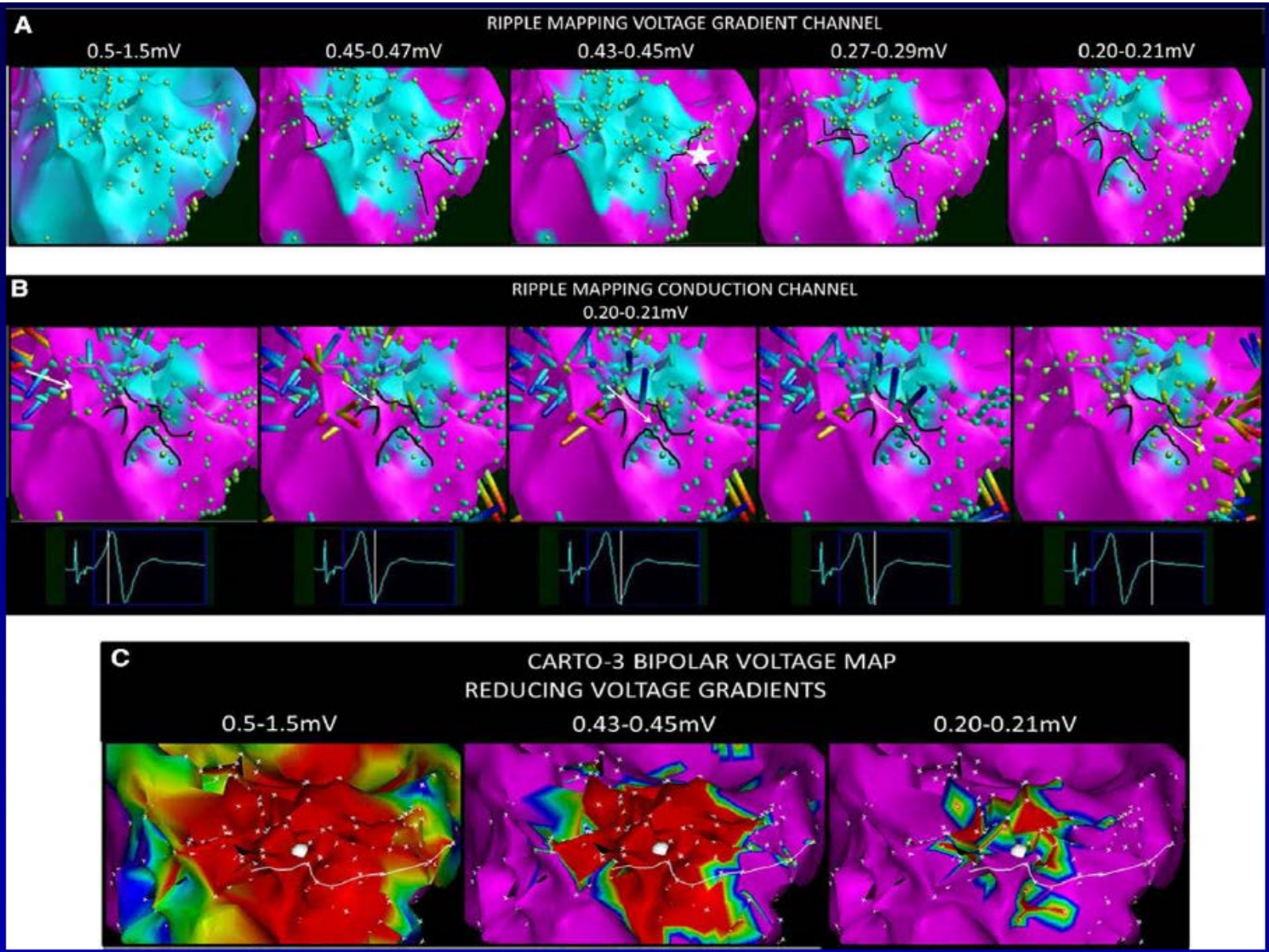


Epicardial ablation

- Ablation site: RV basal inferolateral and anterior epicardium (dark red dot)





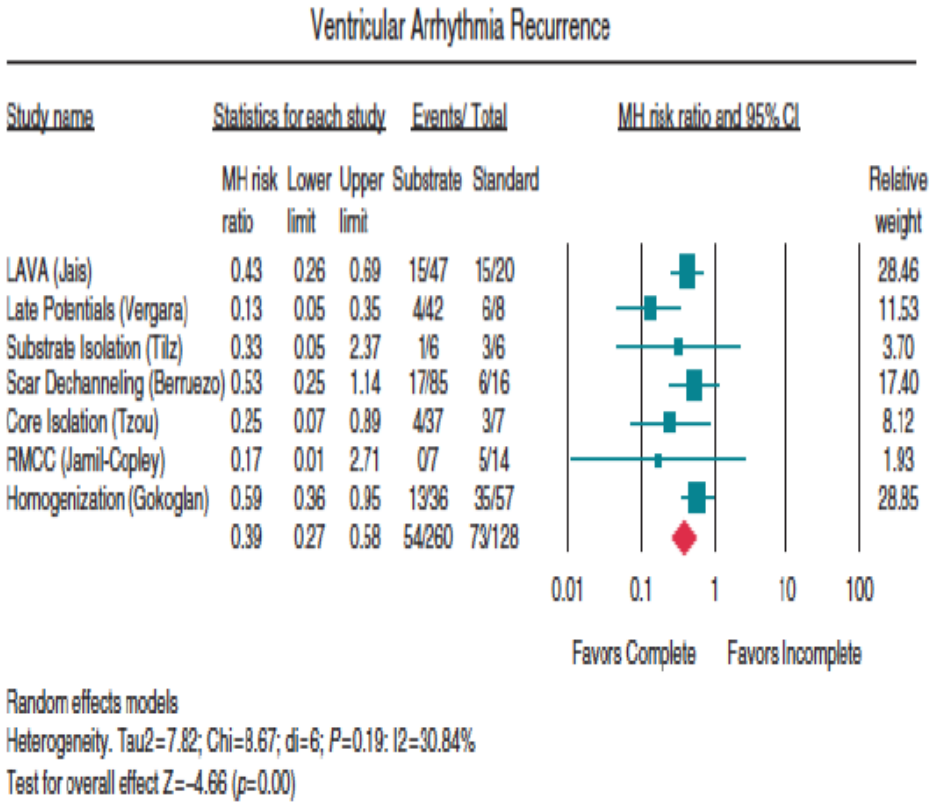


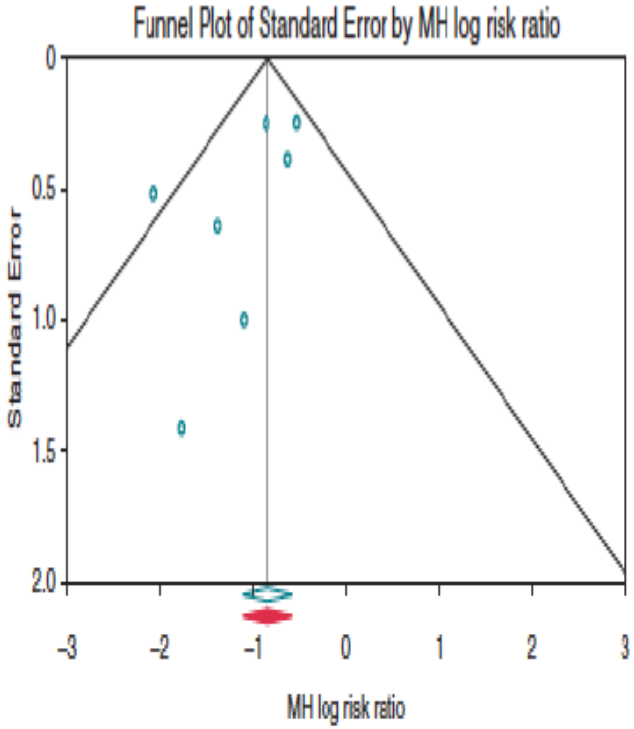
Jamil-Copley et al. Circ Arrhythm Electrophysiol. 2015;8:76-86

- Identifying Conduction Channels
- Measuring Conduction Velocity
- Ablation at the isthmus
- Substrate modification
- Programmed ventricular stimulation (non-inducibility).

Jamil-Copley et al. Circ Arrhythm Electrophysiol. 2015;8:76-86

Complete vs. Incomplete Substrate Modification





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As a result, the same!

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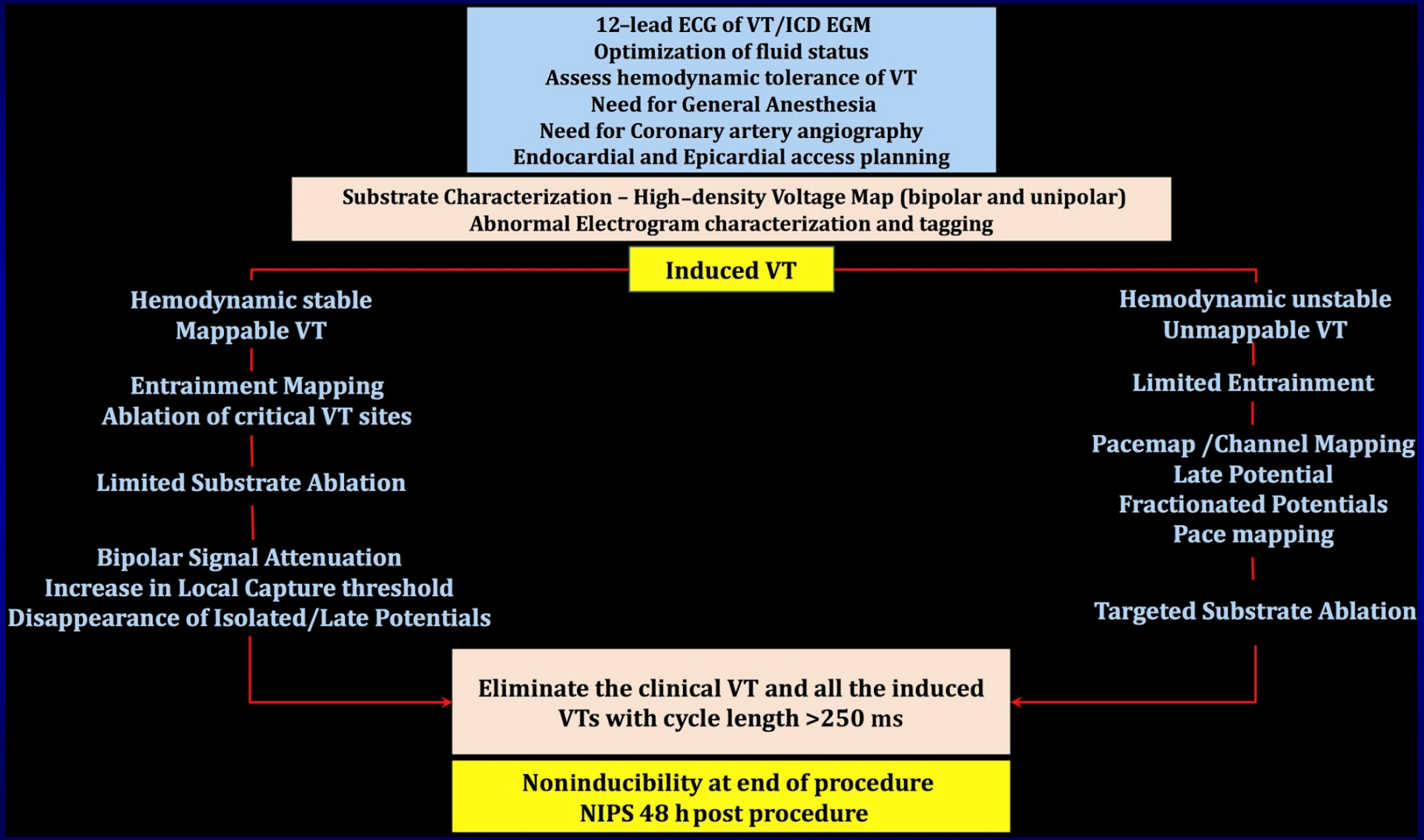
Fig. 4. Strategies for substrate-based ablation. Areas between channels often have electrical activity giving rise to VT substrates (*thunderbolts*); thus, elimination of scar related potentials is a relevant ablation goal and is the basis of different substrate-based ablation strategies. (*A*) Scar dechanneling, (*B*) ablation of LPs and LAVAs, (*C*) CI (core isolation), and (*D*) homogenization of the scar. NSR, normal sinus rhythm.


12–lead ECG of VT/ICD EGM
Optimization of fluid status
Assess hemodynamic tolerance of VT
Need for General Anesthesia
Need for Coronary artery angiography
Endocardial and Epicardial access planning
Substrate Characterization – High–density Voltage Map (bipolar and unipolar)
Abnormal Electrogram characterization and tagging
Induced VT
Hemodynamic stable
Mappable VT
Entrainment Mapping
Ablation of critical VT sites
Limited Substrate Ablation
Bipolar Signal Attenuation
Increase in Local Capture threshold
Disappearance of Isolated/Late Potentials
Hemodynamic unstable
Unmappable VT
Limited Entrainment
Pacemap /Channel Mapping
Late Potential
Fractionated Potentials
Pace mapping
Targeted Substrate Ablation
Eliminate the clinical VT and all the induced
VTs with cycle length >250 ms
Noninducibility at end of procedure
NIPS 48 h post procedure

In Memory of Mark Josephson

Last Year, during the VT Symposium 2016 in New York he said:

Why VT ablations is not so successful

"Inability to define activation of true circuit makes it impossible to identify the "substrate" responsible for the VT.

I think this explains a little bit why most scar related VT ablation are not so successful as we'd like it to be.

At least with 1 or 2 or 3 lesions, unless i mean if we did 400 lesions and destroy the heart, there is no VT, and you have no heart".

I think the biggest problem we have is the inability to define the activation of the true circuit, and if you can't define the circuit you can never define the substrate. To go the other way around is backwards.

감사합니다!