Substrate Mapping during Sinus Rhythm : How to Improve Clinical Outcomes

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Agenda

1. Case - substrate mapping in structural VT

2. Mapping catheters and electrogram quality
   - multi-electrode, Omnipolar

3. Mapping strategy (substrate definition)
   anatomic – determined by voltage only
   (encircle or homo)
   functional - LAVA, dechanneling,
   isochronal crowding (ILAM), physioVT, DEEP,

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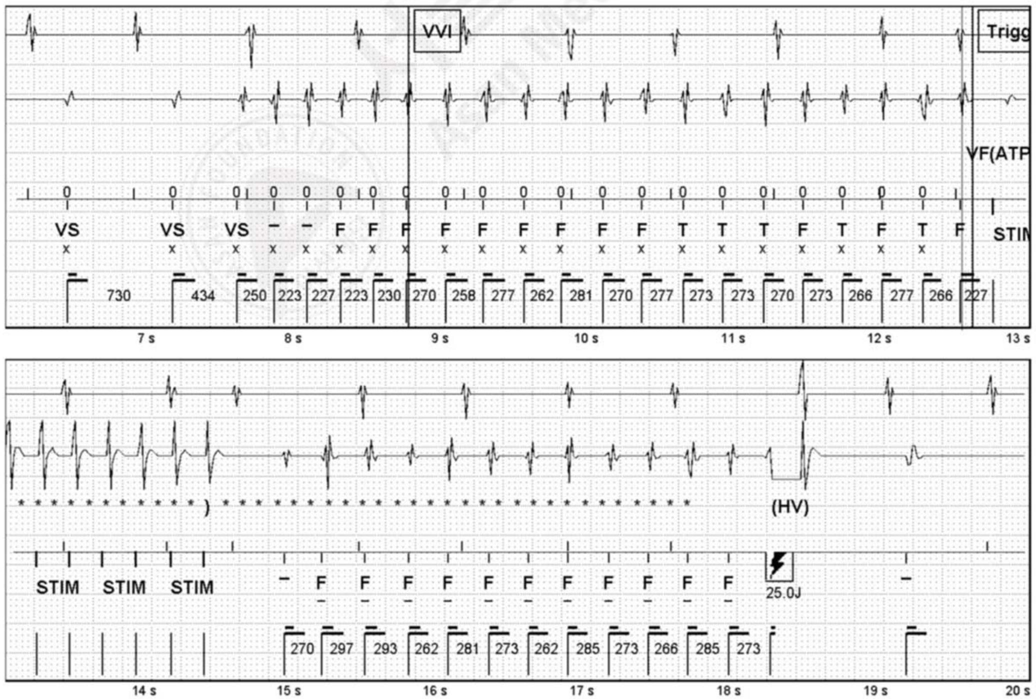
[I]

Case, M/74

#1. Dilated cardiomyopathy
#2. Spinal stenosis
#3. Documented VT - s/p ICD('11.11.14)

2021.03.17 Squeezing chest pain during walking- ICD shock x1
pain subsided after shock -> 00 Univ. hospital ER
2021.03.24 x1 shock at rest (ass w chest pain)
2021.03.25 x3 shock during sleep
2021.03.26 referred for catheter ablation



Fortify™ DR 2231-40Q ICD (625811 prC.D.95)
Merlin™ PCS (#12050927 3330 v25.0.2 rev 4)

VT/VF Episode 16 of 16 Page 2 of 3
26 Mar 2021 16:14

Episodes Summary

Page 1 of 1

Episodes Last Cleared	26 Mar 2021 16:24	Last Read	26 Mar 2021 16:13
SEGMs Last Cleared	28 Jan 2021 8:19		

Therapy Summary

	VT	VF
ATP Delivered	14	2
Shocks Delivered	3	2
Max Energy Shocks	0	0

Last HV Lead Impedance 39 Ω

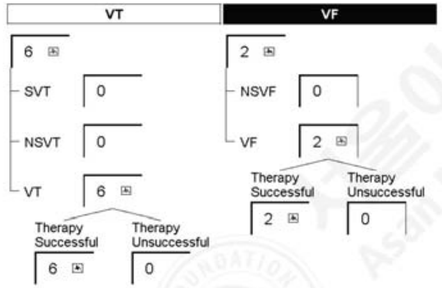
Total Aborted Shocks 0

Results of ATP Delivery

	VT	VF
Episodes Terminated	11	0
Episodes Not Terminated	3	2
Accelerations	0	

Episode Tree

Total VT/VF Episodes 8
SVT Episodes 0

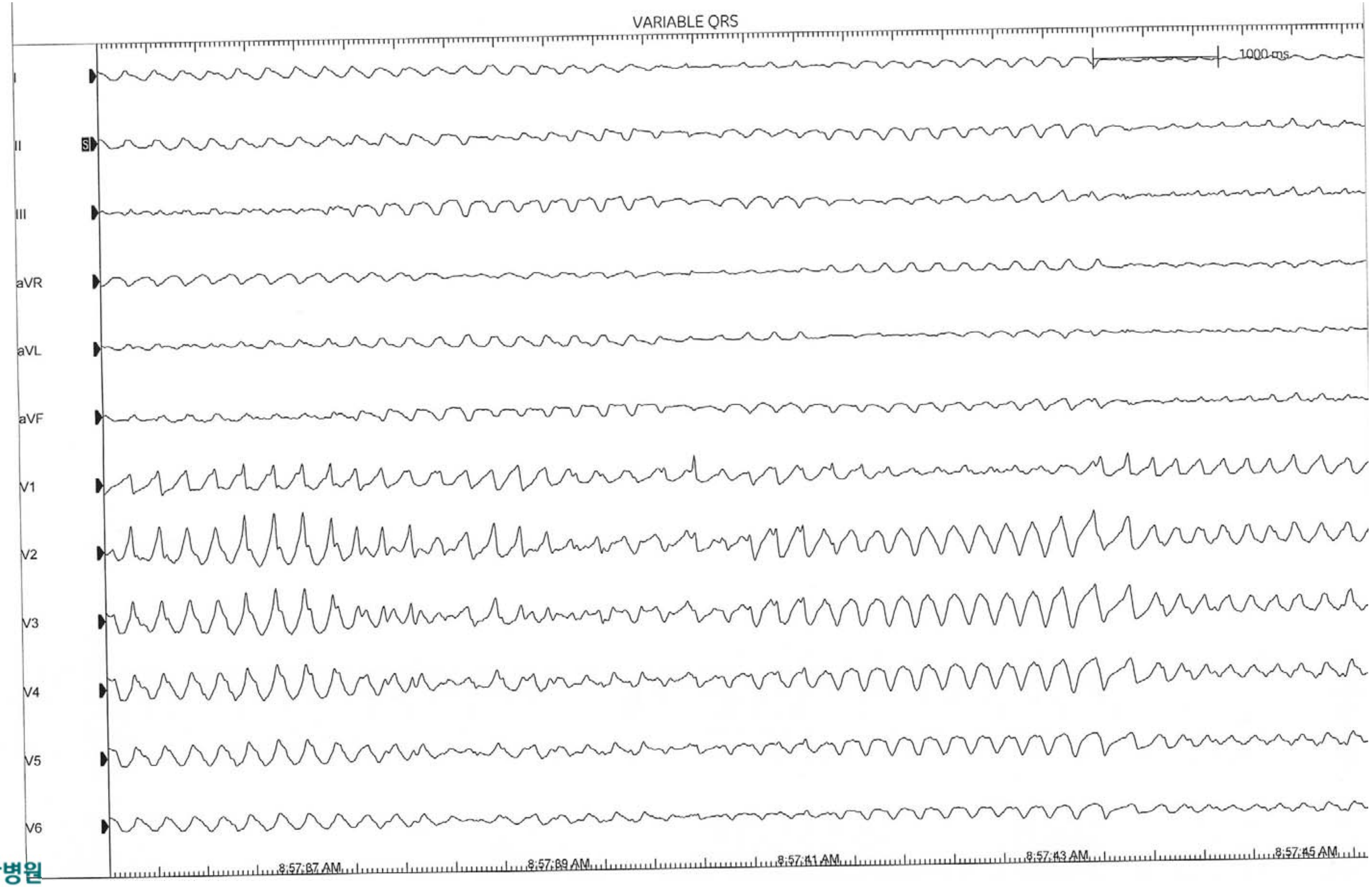


VT/VF Episodes

Date / Time	Type	Rate (min-1)	Duration (M:S)	Therapy Delivered	Alerts
25 Mar 2021 21:59	VF	222	00:15	ATP, 25J	x1
25 Mar 2021 21:58	VF	222	00:15	ATP, 25J	x1
25 Mar 2021 21:58	VT	171	00:44	ATP X 3, 5J	x2
25 Mar 2021 21:57	VT	171	00:15	ATP	x1
25 Mar 2021 21:57	VT	171	00:15	ATP	x1
25 Mar 2021 21:57	VT	171	00:13	ATP	x1
25 Mar 2021 21:56	VT	176	00:16	ATP X 2	x1
25 Mar 2021 21:53	VT	169	00:21	ATP	x1

Other Episodes

Date / Time	Type	Peak A / V Rate (min-1)	Duration (D:H:M:S)	Alerts
26 Mar 2021 10:42	Morphology Template Update			
25 Mar 2021 21:57	AMS	640 / 169	0:00:00:10	
25 Mar 2021 21:57	AMS	614 / 82	0:00:00:02	
25 Mar 2021 21:56	AMS	614 / 169	0:00:00:12	
25 Mar 2021 21:54	AMS	640 / 169	0:00:01:30	



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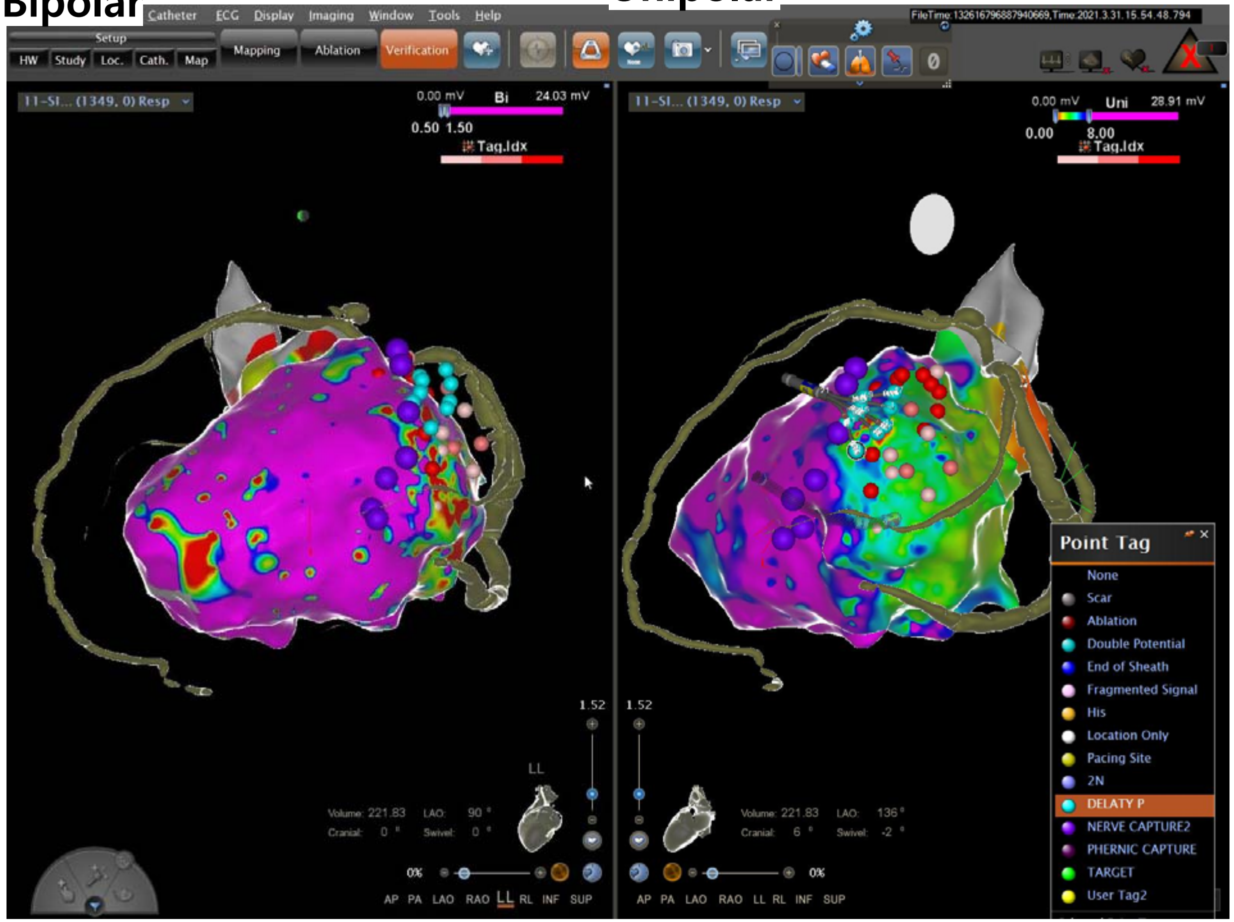
Scar distribution

Bipolar Unipolar



<u>Bipolar voltage amplitude</u>

3.5mm Ablation: <u>0.5-1.5mV</u>

Penta-Ray: 0.2-<u>1.0mV</u>

<u>Unipolar voltage amplitude</u>

(using ablation catheter)

8.3mV (LV), 5.5mV (RV)

cf 5.1mV (LV) 4.4mV (RV)

J Am Heart Assoc. 2013;2:e000215
Circ Arrhythm Electrophysiol. 2011;4:49-55
Heart Rhythm 2011;8:76–83

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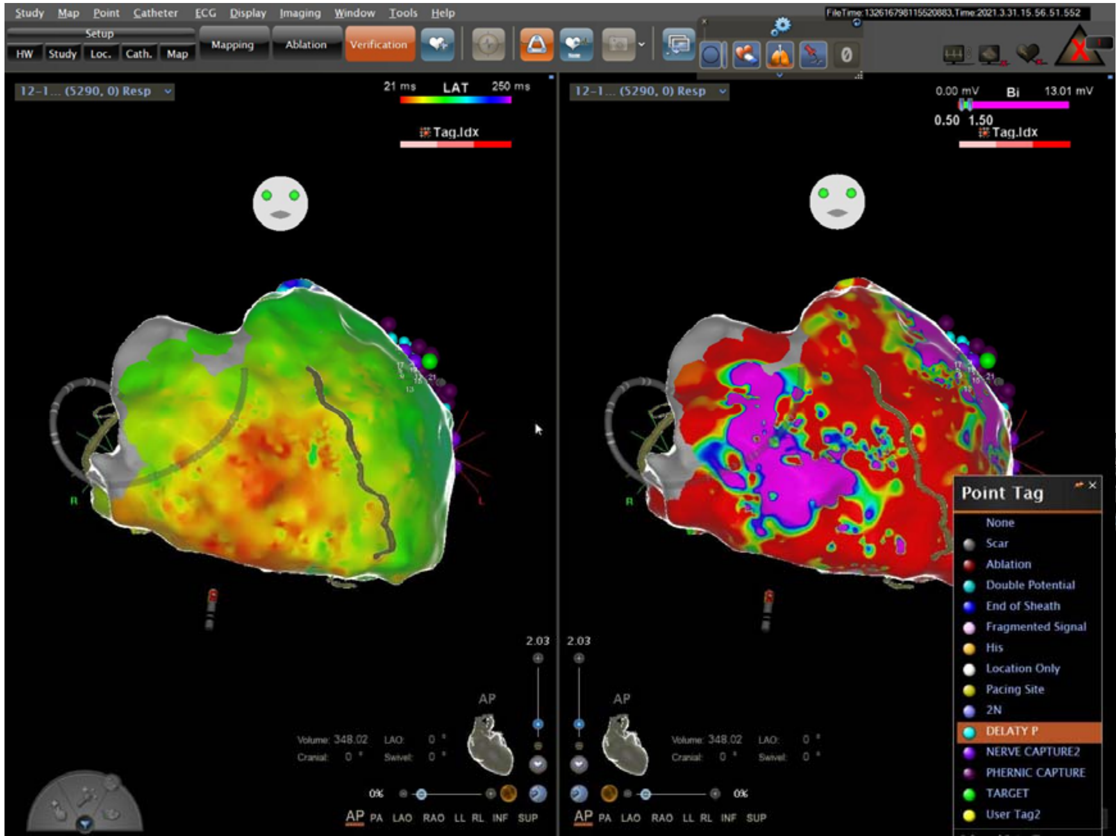

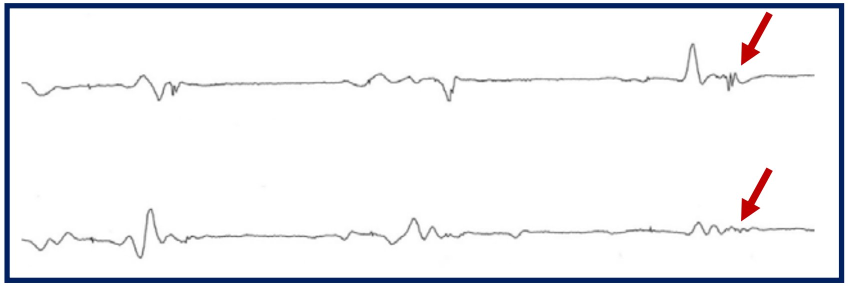

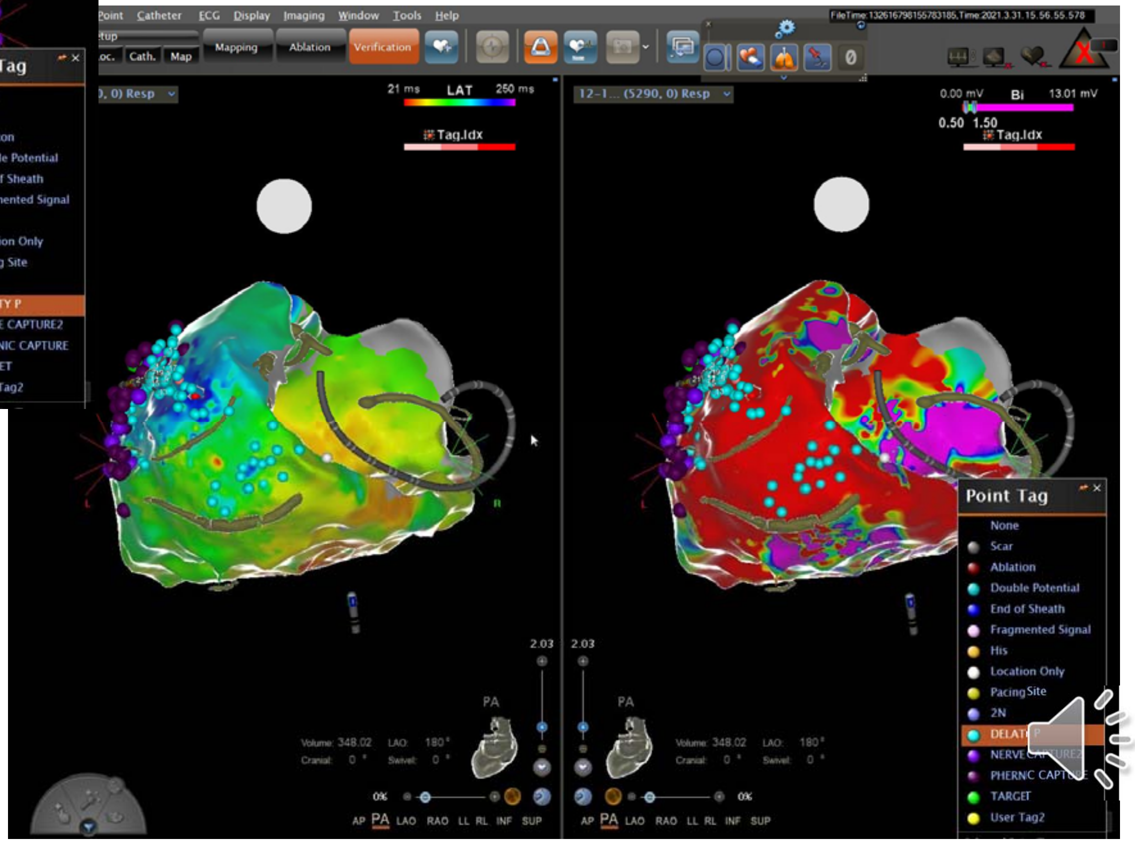

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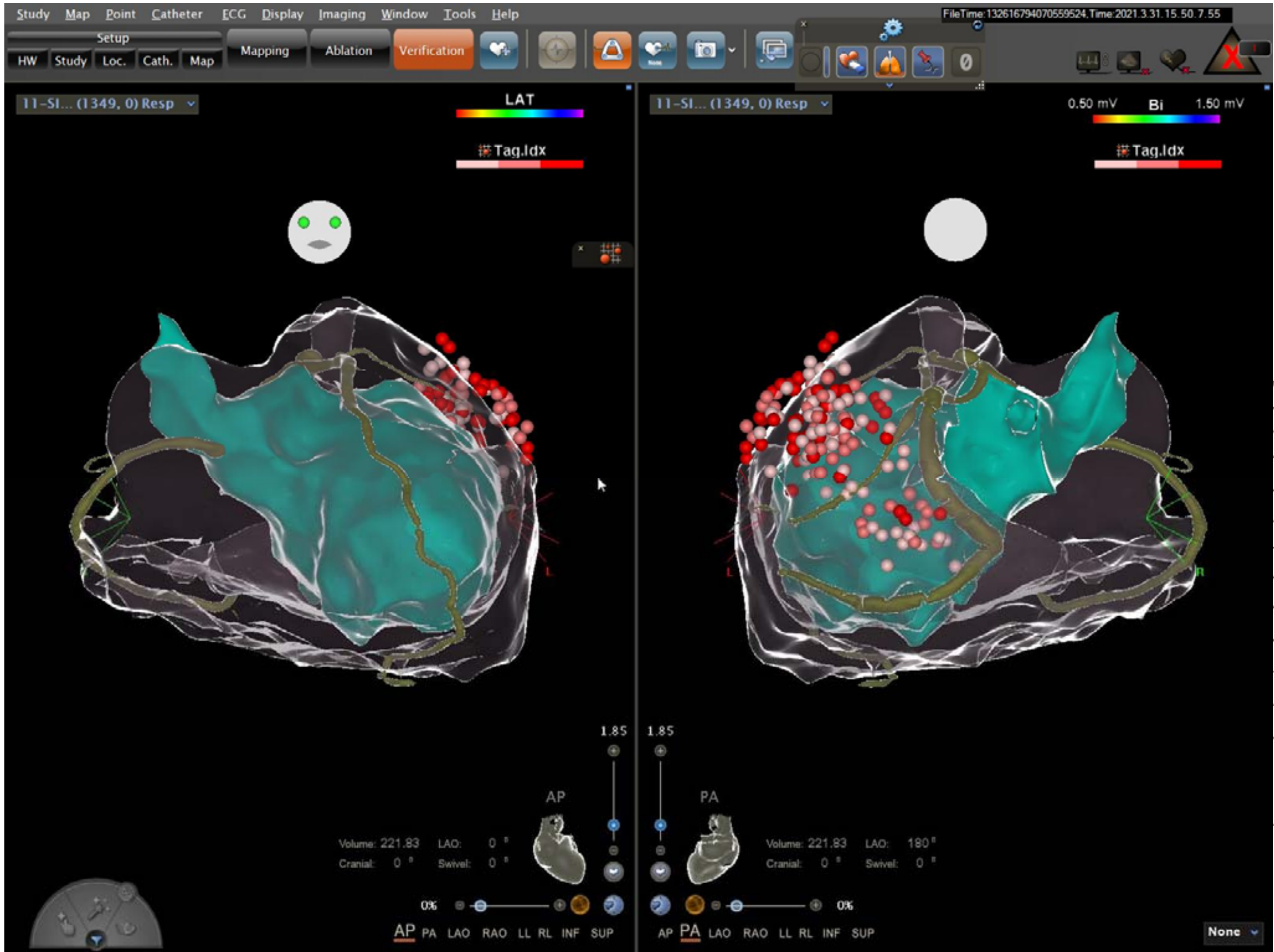

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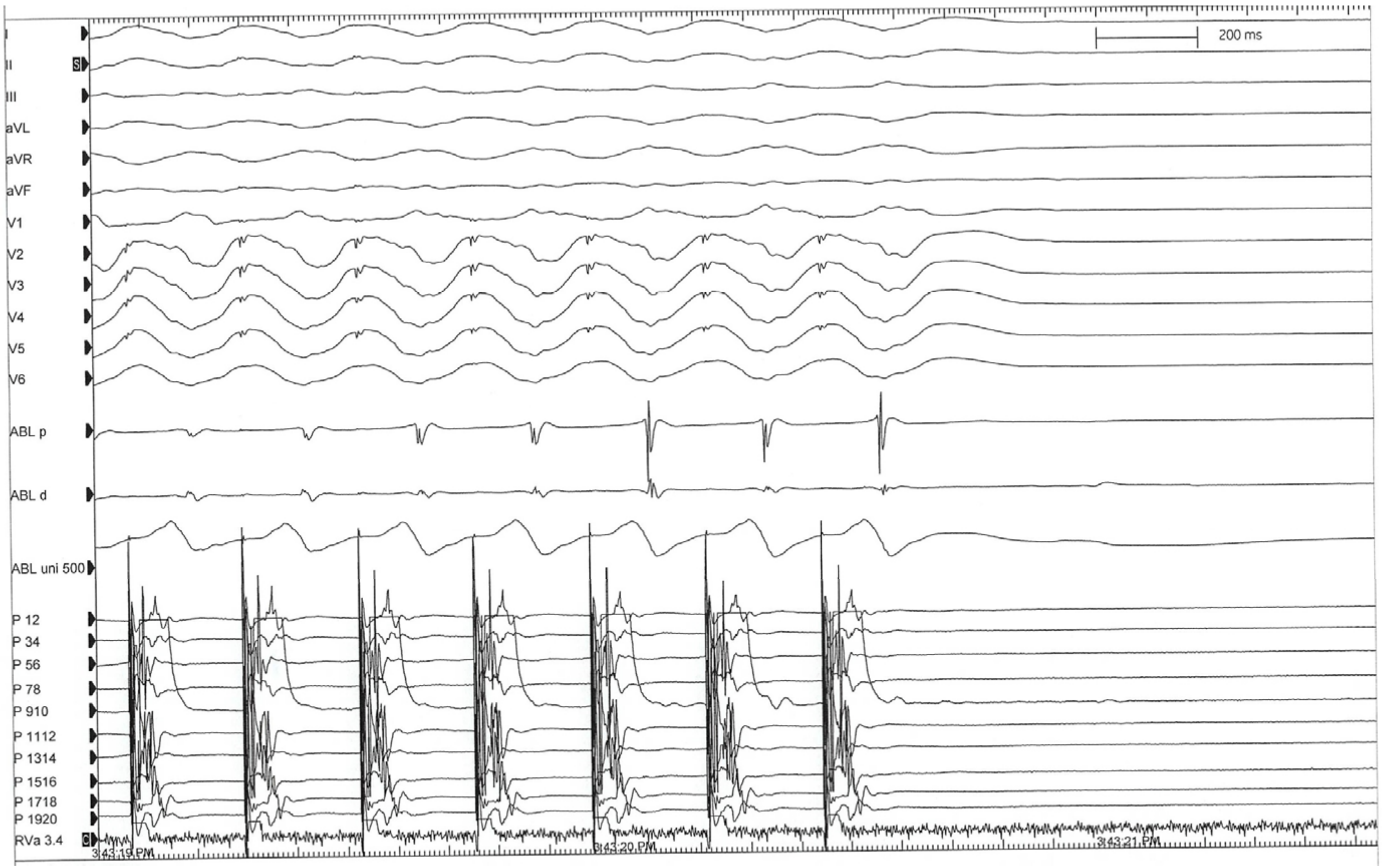
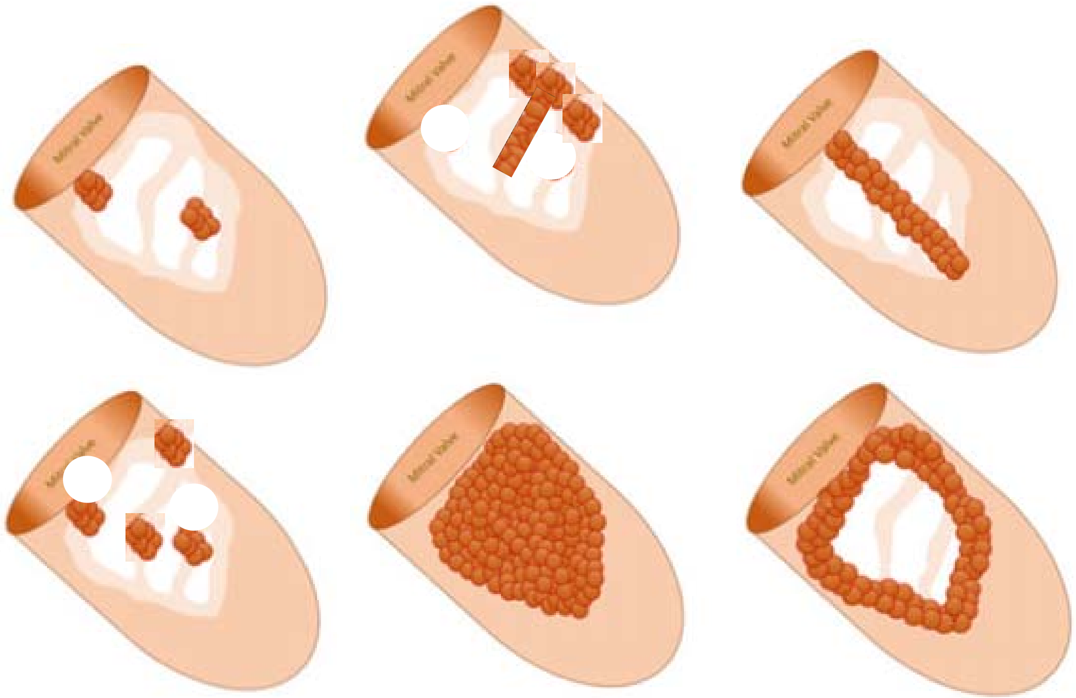
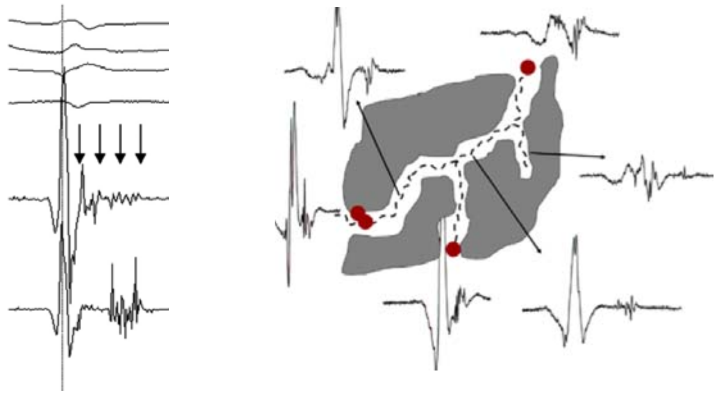

I
II
III
aVL
aVR
aVF
V1
V2
V3
V4
V5
V6
200 ms
ABL p
ABL d
ABL uni 500
P 12
P 34
P 56
P 78
P 910
P 1112
P 1314
P 1516
P 1718
P 1920
RVa 3.4
3:43:19 PM
3:43:20 PM
3:43:21 PM

Substrate modification strategy

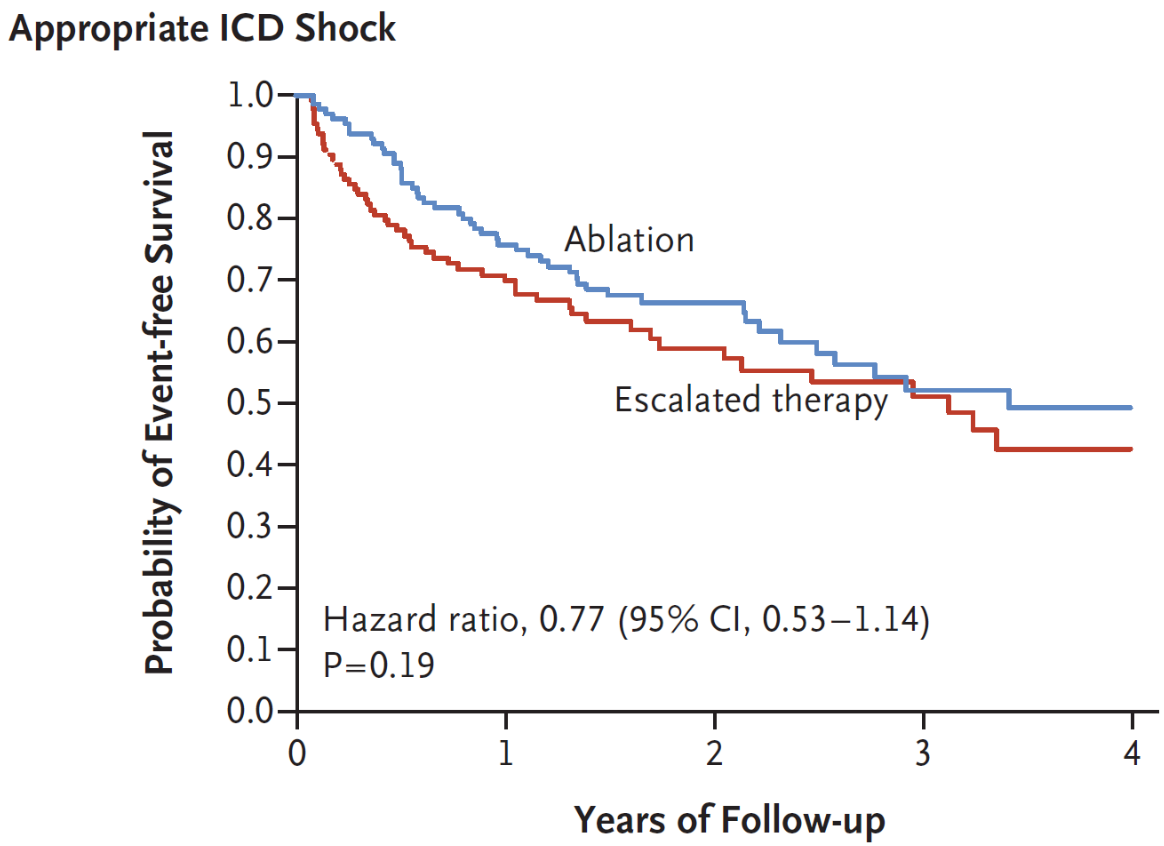


Channels ablation – EUS (Soejima), voltage-define CC (Arenal)
Short linear ablation parallel to the border zone (Soejima)
Linear lesion connecting dense scar to Nl myocardium (Marchlinski)
Circumferential scar isolation (Tilz)
Scar homogenization (Di Biase)



LAVA (local abn. ventricular activity) ablation (Jais)
Scar dechanneling (Berruezo)

Ventricular Tachycardia Ablation versus Escalation of Antiarrhythmic Drugs (VANISH)



Results of VT ablation, Satisfactory?

N Engl J Med 2016;375:111-21

[III]

Importance of mapping electrodes

1. Ablation catheter (3.5mm tip)
2. Decapolar catheter
3. Penta-Ray, Lasso,
4. HD grid, AFocus
5. Intellimap Orion

Multipolar mapping electrodes (items 2–5)

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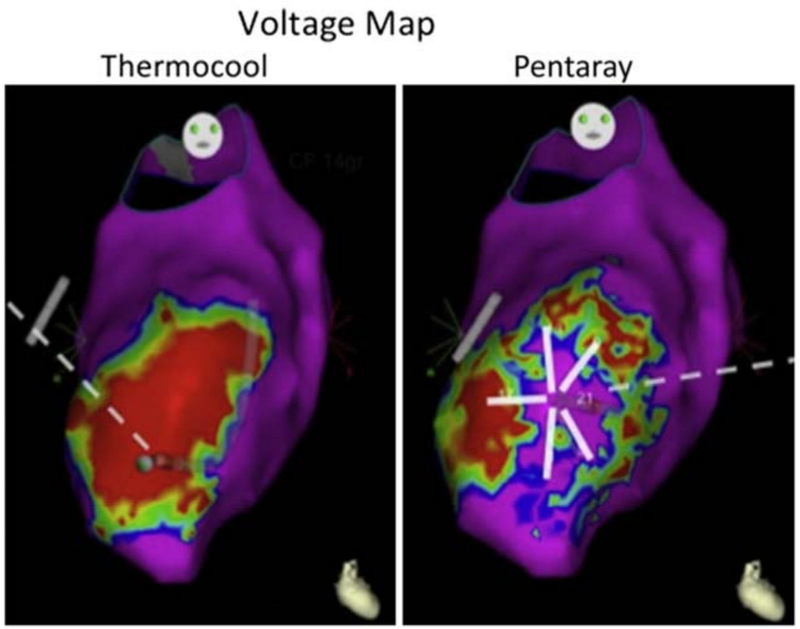
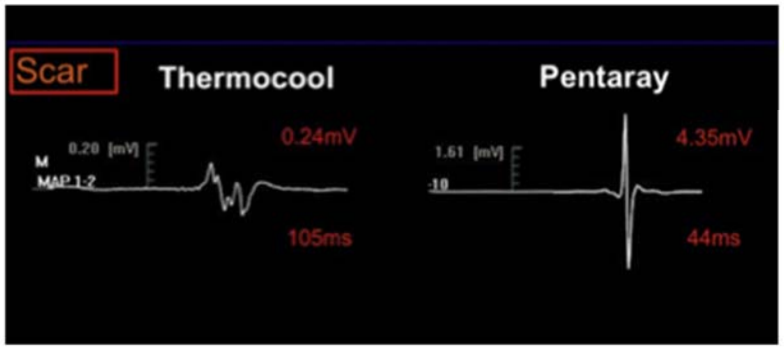
Advantages

1. **Ultra-high density (>1,000 points) – speed, density, resolution**
2. **Small electrode size and spacing–better tissue characterization**
3. **Mapping system - rapid collection with automated interpretation**

Curr Treat Options Cardio Med (2018) 20: 34
Circ Arrhythm Electrophysiol. 2016;9:e003841

The Effect of Electrode Size and Inter-electrode Spacing on Electrograms



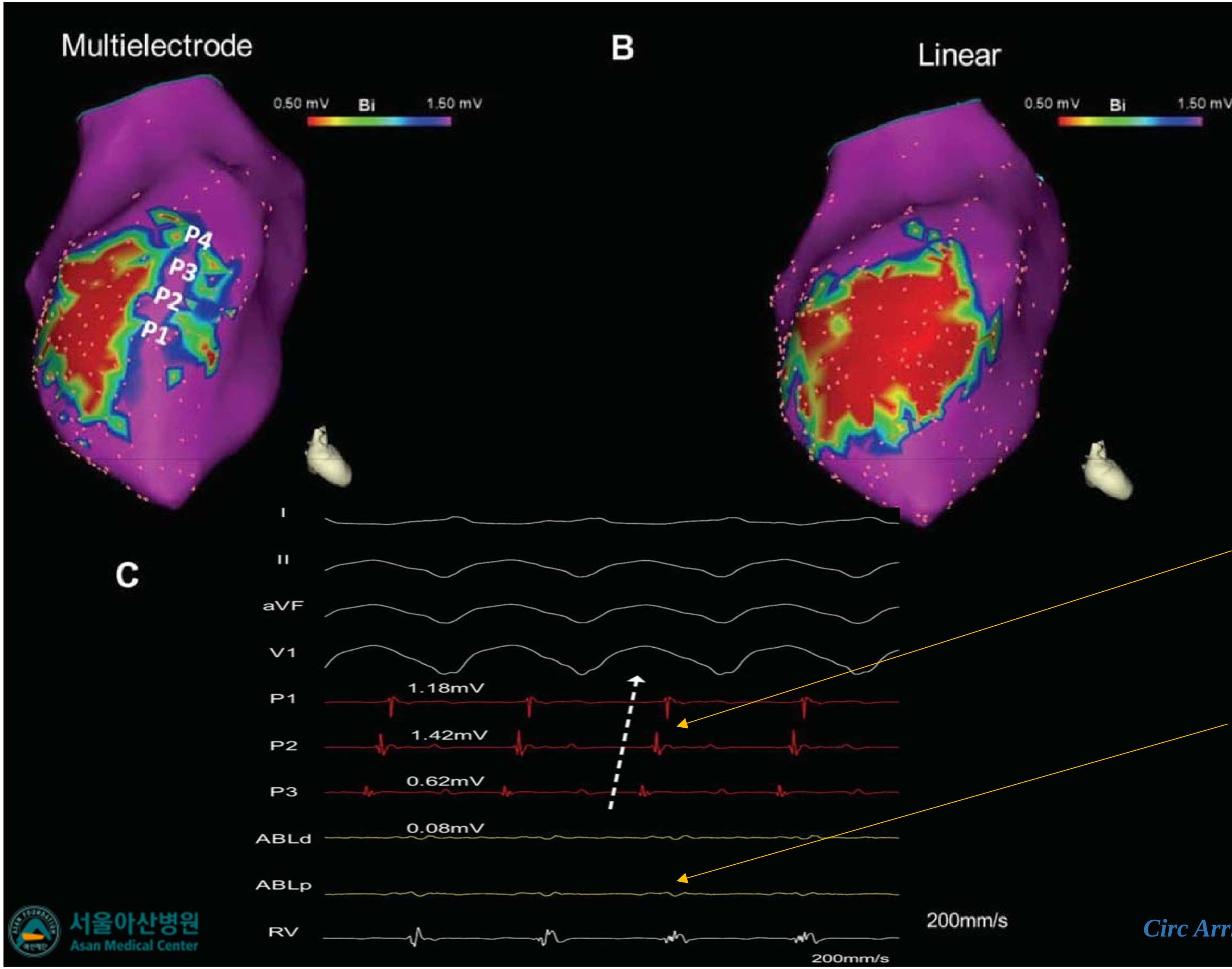


Recordings from the same site with a Pentaray show normal bipolar amplitude and width.

Large tip electrodes record activity from over a large area, picking up electrogram data representative of a larger tissue size. (low amplitude, longer-duration signals in areas of heterogeneous scar).

Catheters with **smaller electrodes** (0.4 to 1.0 mm) record high-voltage signals at similar scar sites, thus identifying surviving myocardial bundles.

J Am Coll Cardiol EP 2015;1:341–52



Multielectrode-mapping catheters, identify a channel of healthy subendocardial tissue, but not with a linear catheter.

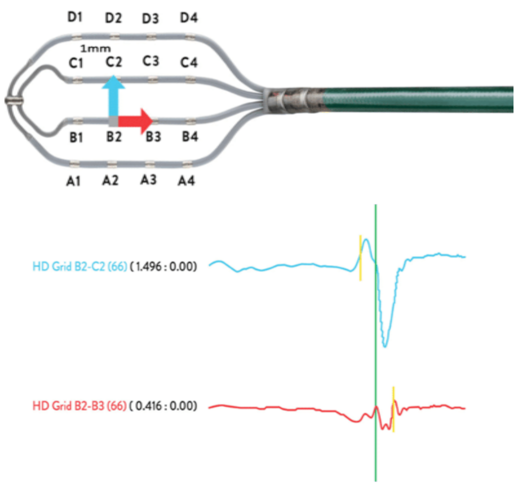
Multielectrode:
- near-normal bipolar voltage
- 0.62–1.42 mV

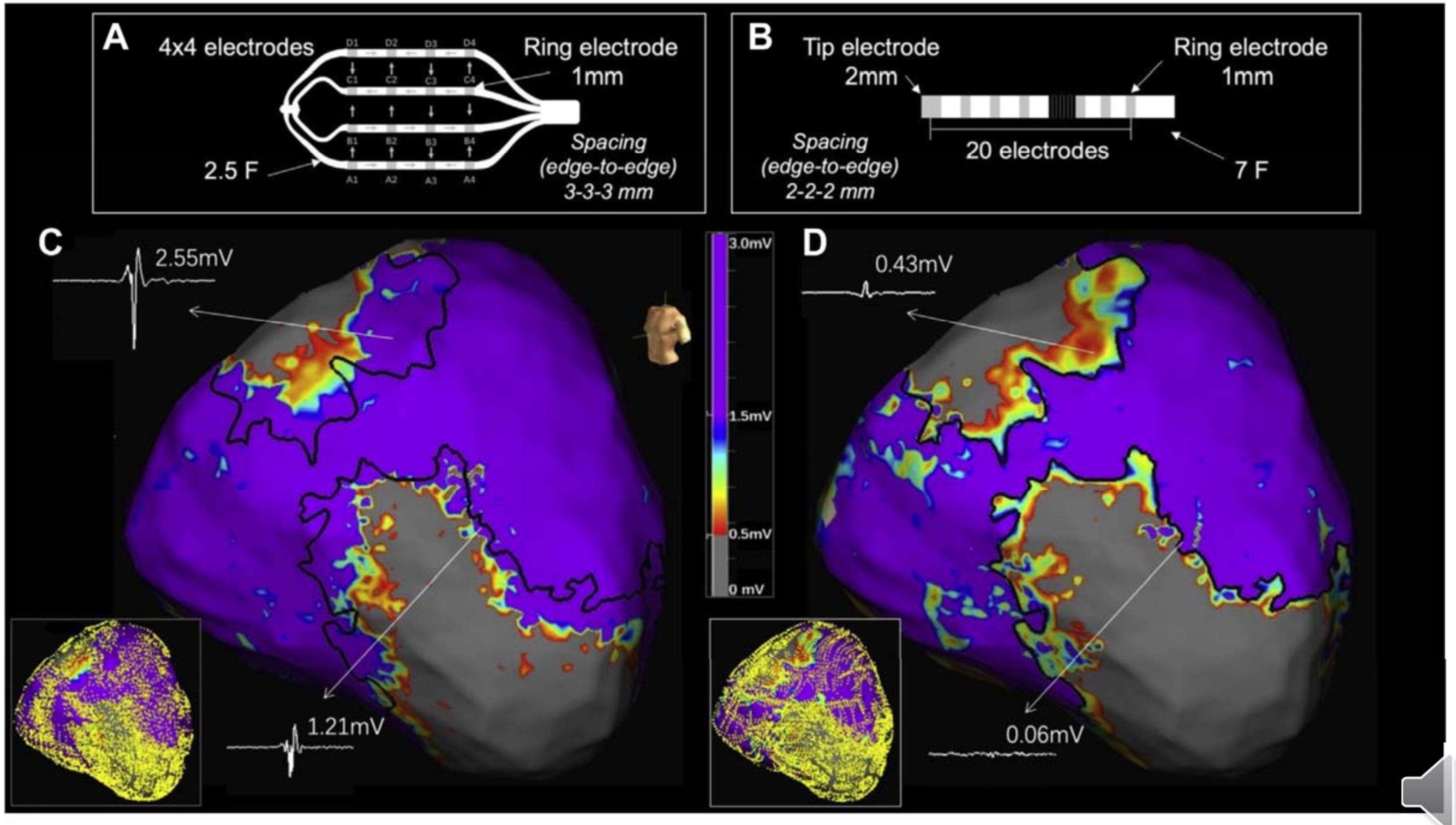
Ablation catheter:
- at similar position
- fractionated low amplitude
- 0.08 mV

Circ Arrhythm Electrophysiol. 2016;9:e003841

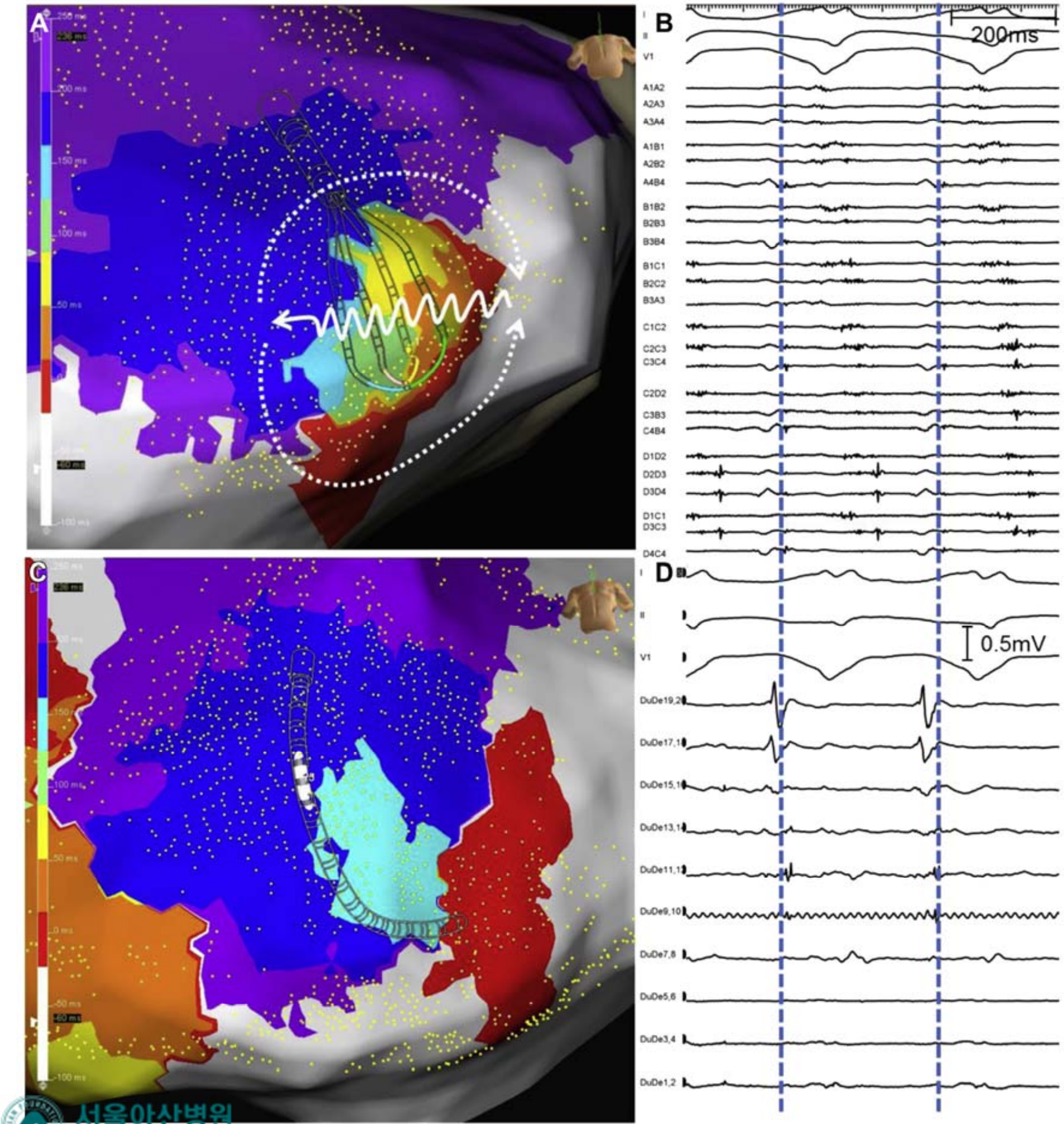
Comparison of Bipolar Voltage Maps Using a Grid Catheter vs a Linear Duodecapolar Catheter

Voltage recordings in direction independent mapping: The amplitude of EGMs recorded by grid catheter is notably higher than that recorded by linear catheter, whereas the low voltage substrate size is smaller in dense scar (<0.5 mV) and border zone(<1.5 mV).





J Am Coll Cardiol EP 2020;6:311–23



Diastolic potentials during **early and mid-diastolic** recorded by the **grid catheter** were not detected using the **linear catheter**. The proximal (orange) and central isthmus (yellow and green) were not seen using the duodecapolar, which created a false activation gap.

J Am Coll Cardiol EP 2020;6:311–23

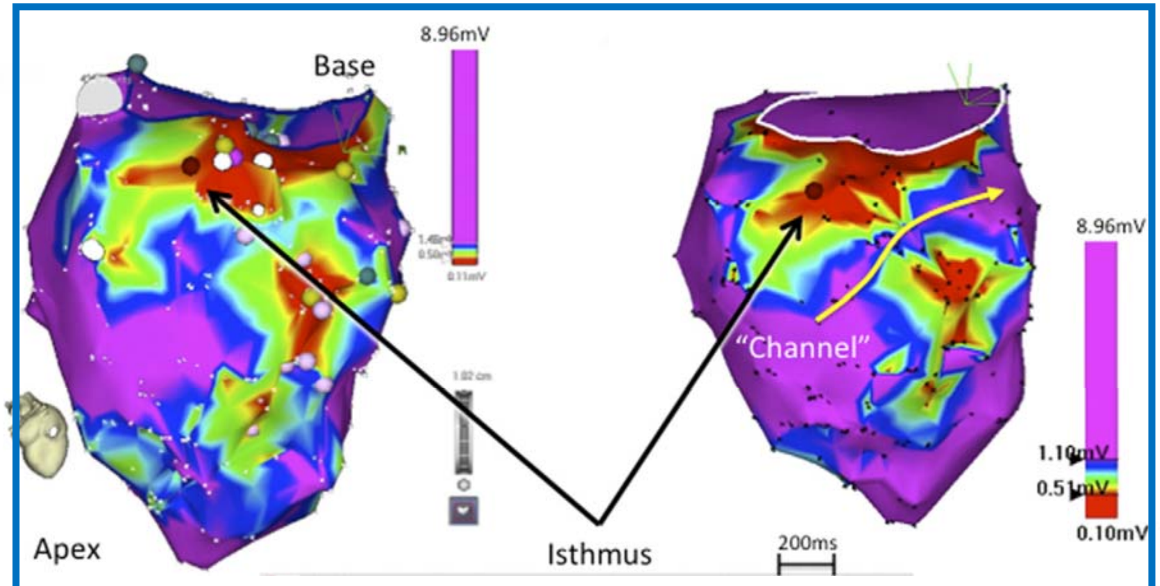
[IIII]

Better Identification of abnormal substrate

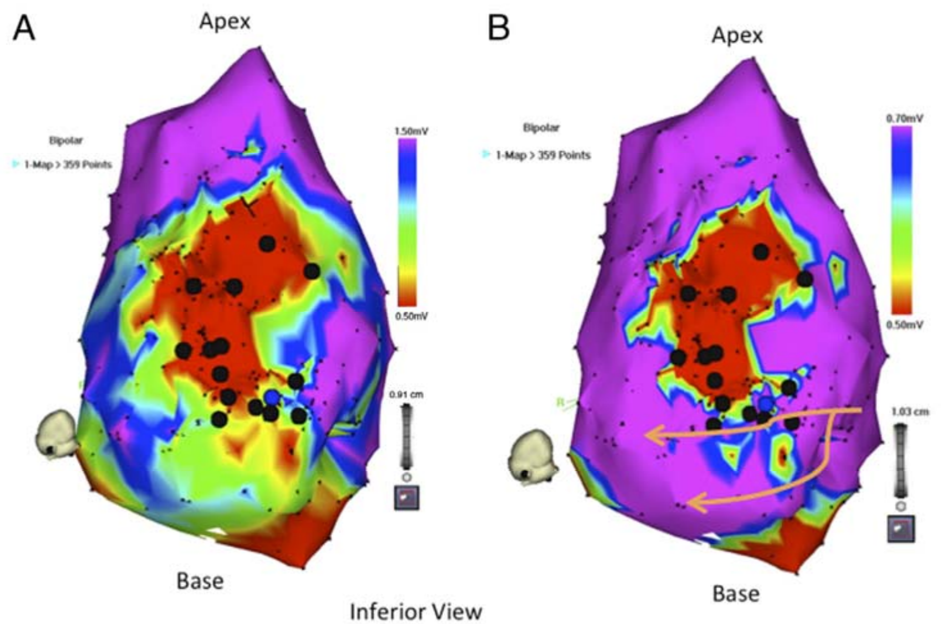
1. Voltage map: anatomical
2. Functional: LAVA, channel
3. New mapping technology

   : ILAM, DEEP or hidden slow conduction

Channels were identified in 88% of VT by adjusting the voltage limits. However, the SP of those channels predicting VT isthmus was only 30%. The presence of ILPs inside the voltage channel significantly increases SP (85%) for identifying the clinical VT isthmus.



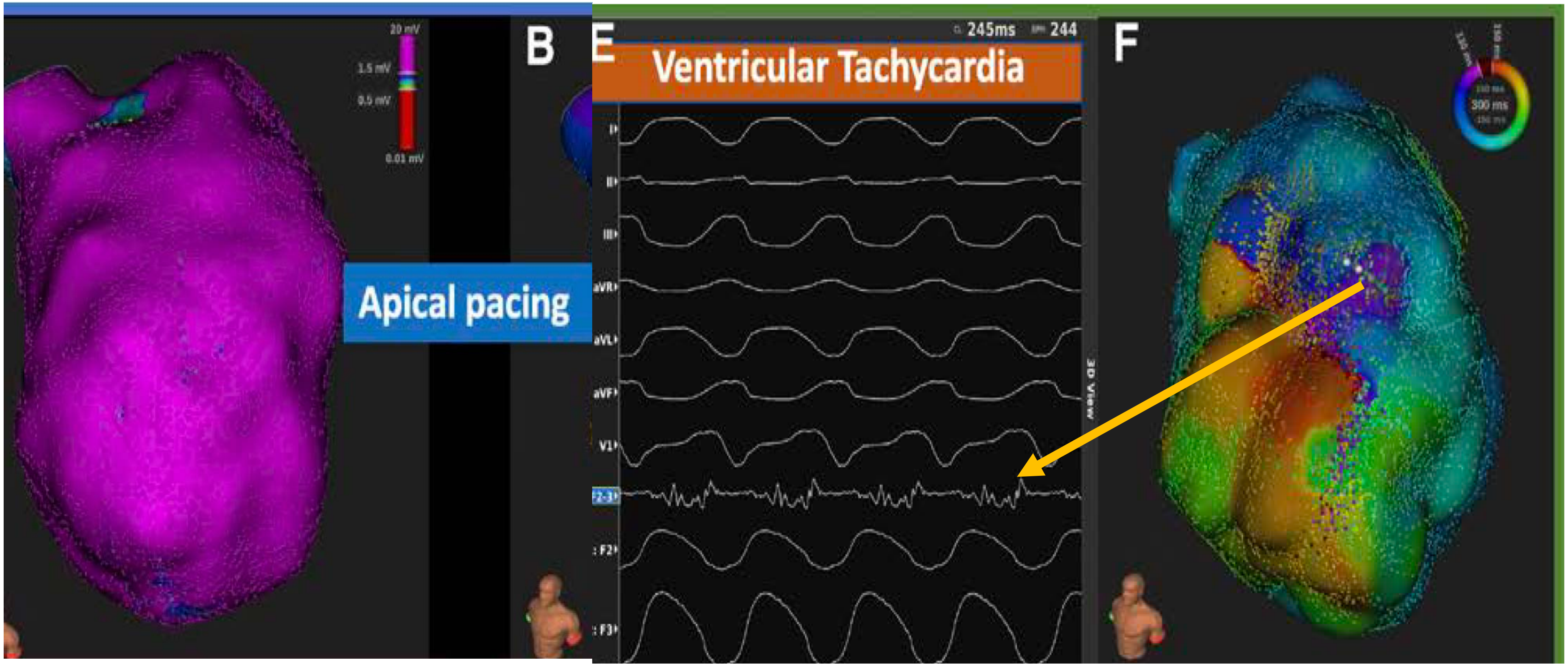
VT Isthmus = Channel



Nonclinical Isolated late potentials

Gerstenfeld et al. J Am Coll Cardiol 2013;61:2088–95

The relationship btw voltage, conduction, & VT isthmus



PHYSIO-VT by Anter et al
Circ Arrhythm Electrophysiol. 2020;13:e008625

Substrate mapping of VT

- majority of VTs are not hemodynamically tolerated
- lack of a uniform definition of the substrate,
- inadequate sensitivity, limited specificity to DDx btw arrhythmogenic vs nonspecific scar
- homogenization, core isolation, elimination of local fractionated potential, dechanneling

Elad Anter et al
Circ Arrhythm Electrophysiol. 2020;13:e008625

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[III]

Better Identification of abnormal substrate

1. Voltage map: anatomical
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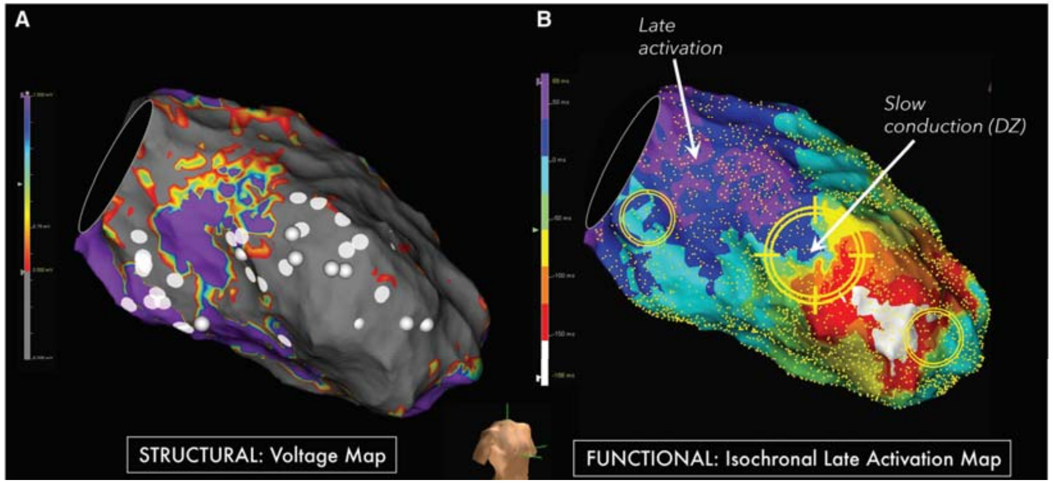
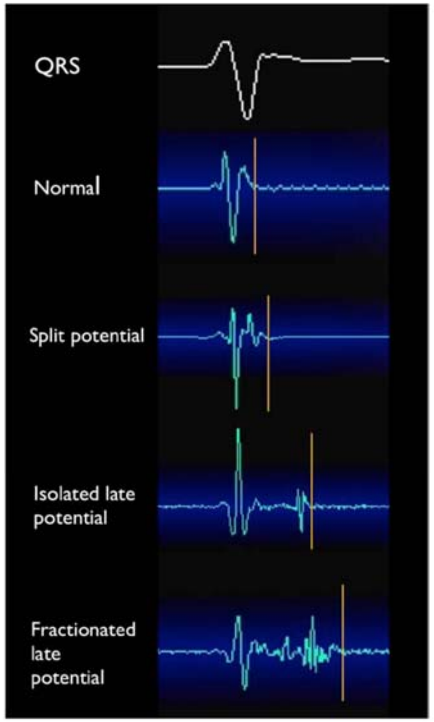
Isochronal Late Activation Map (ILAM)

A New Functional Substrate Mapping Strategy
Guide targeted ablation, obviating need for extensive RF delivery
Regions with <u>isochronal crowding (deceleration zones)</u>
- niduses for reentry, predictive of VT termination

<u>Each electrogram was timed at the offset</u> of the local bipolar electrogram deflection, signifying the completion of local activation. The offset was chosen because of a higher degree of <u>reproducibility and less interobserver variability</u> than the onset, maximum dV/dT, or amplitude of a LP, which are more arbitrary and subjective at sites with continuous and fractionated activity.





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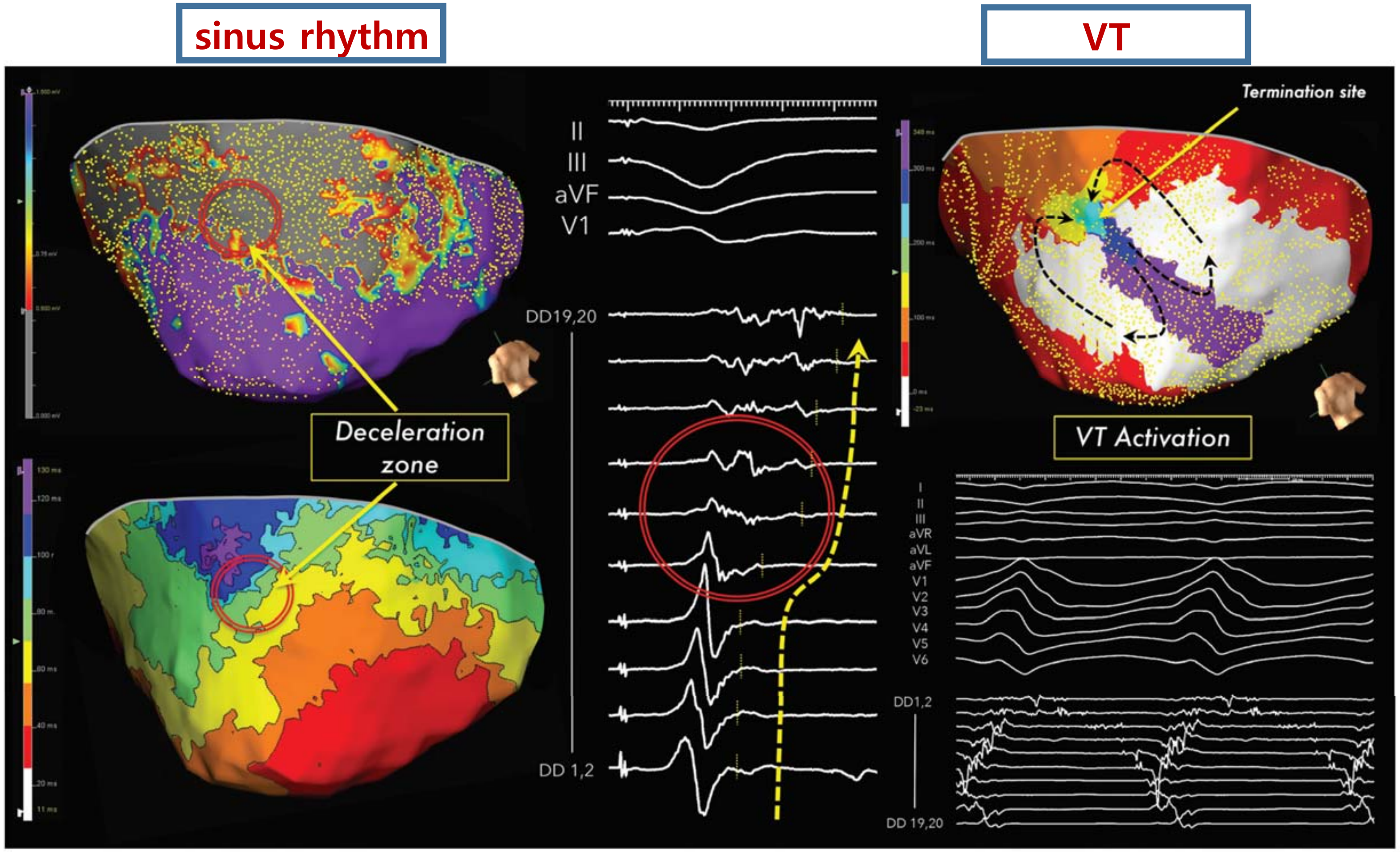
Circ Arrhythm Electrophysiol. 2015;8:390-399
Circulation. 2019;140:1383–1397

Correlation between the VT circuit with critical diastolic pathway and deceleration zone (DZ) location during sinus rhythm



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Circulation. 2019;140:1383–1397

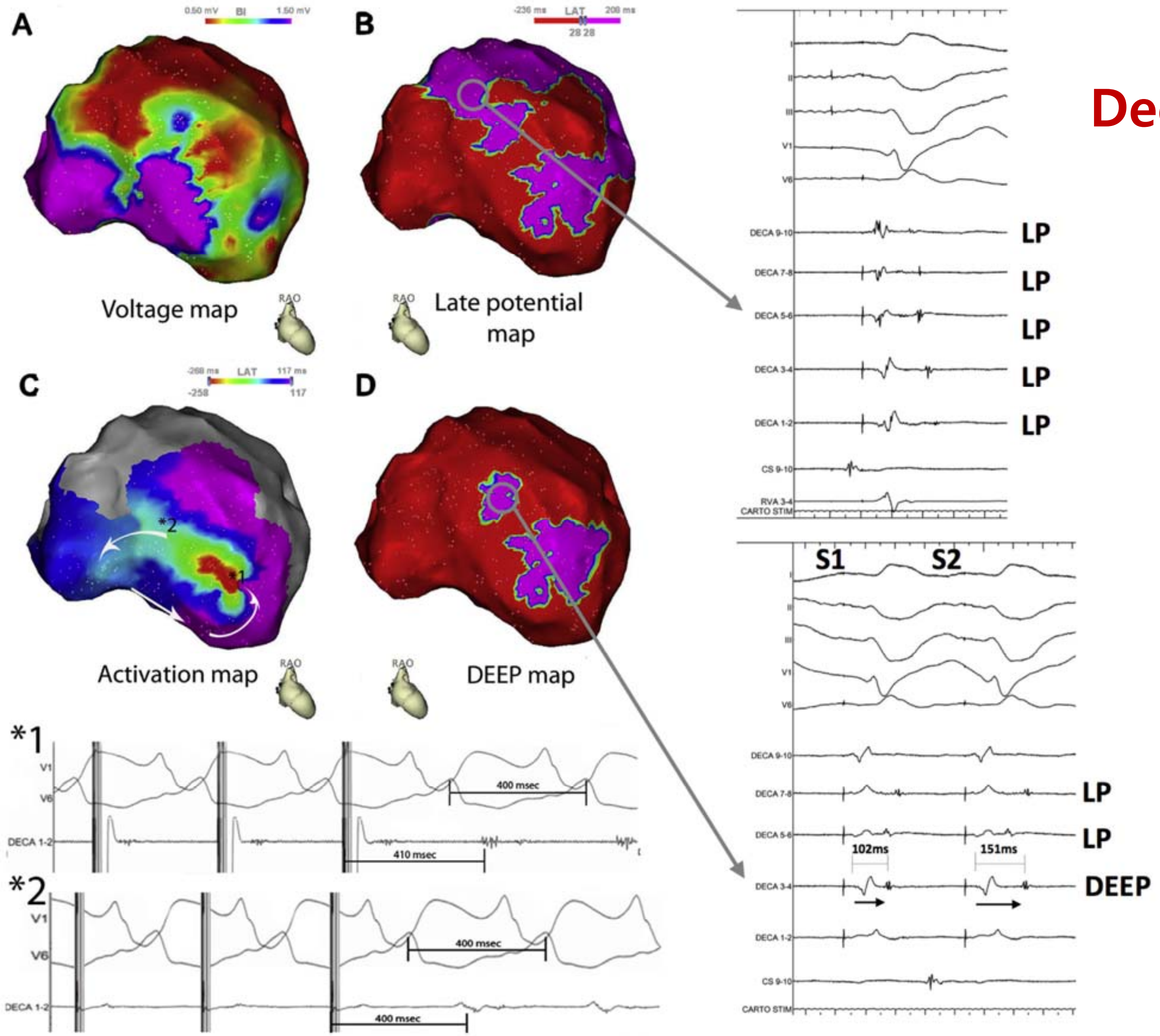
Decrement Evoked Potentials (DeEP)

Abnormal potentials w **decremental conduction** as a response to extra-stimulus pacing (decremental conduction/unidirectional block-necessary slow conduction for reentry)

Evoked potential by extrastimulation: Better co-localize within **diastolic pathways** of VT circuits than **conventional late potentials** - high specificity for the diastolic isthmus

Drive train (S1) from the RV at 600 ms with a single extra stimulus (S2, coupled at 20 ms above the ventricular ERP.
If the local LP bipolar EGM after the S2 was delayed by>10 ms, the LP was defined as a DEEP. All DEEP and non-DEEP-LPs were given a different annotation marker in the substrate map.

J Am Coll Cardiol EP 2018;4:307–15
Zaid Aziz, Roderick Tung
Curr Treat Options Cardio Med (2018) 20: 34



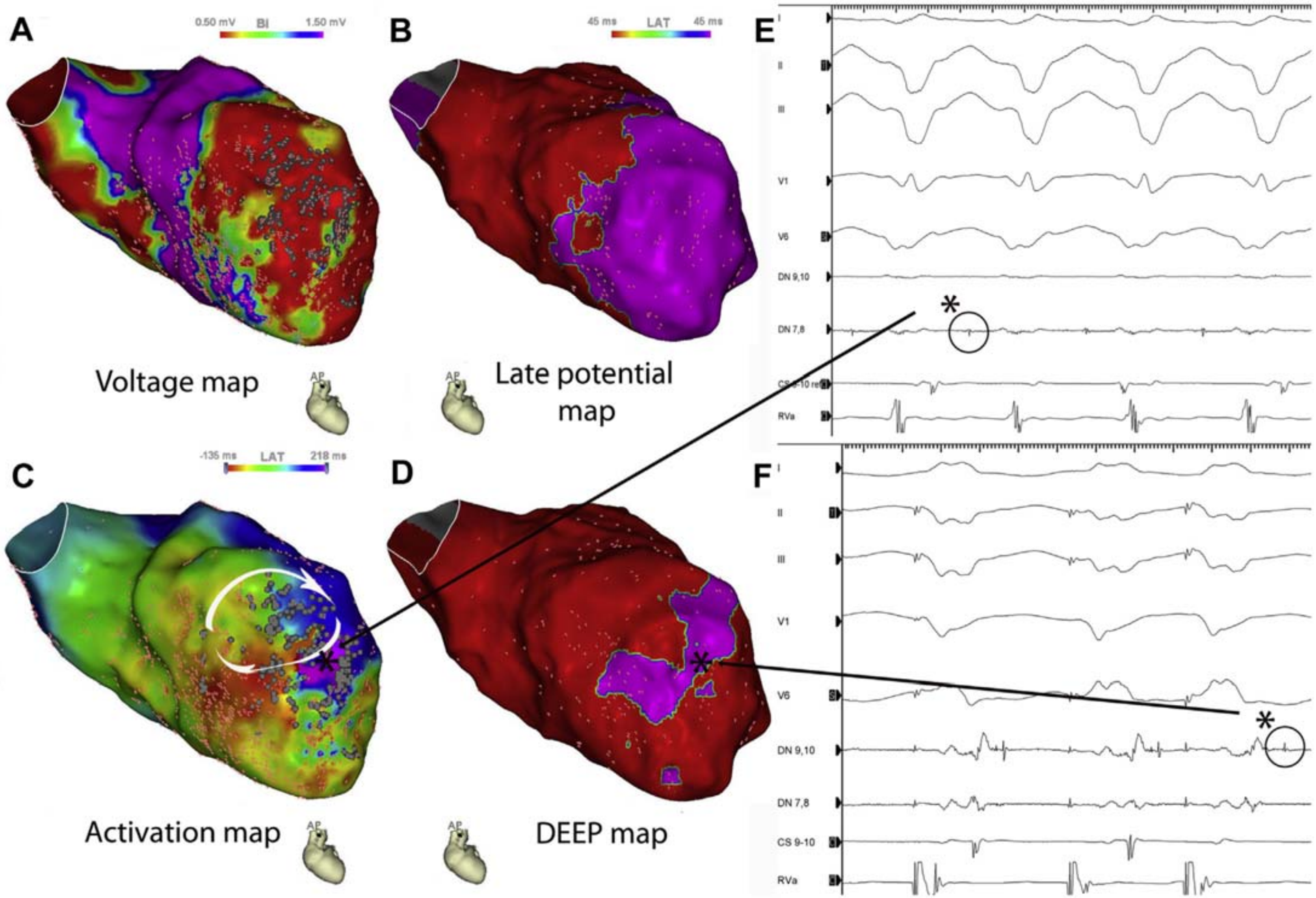
Decrement Evoked Potentials (DeEP)

Mechanistic and physiological approach to identify <u>functional</u> substrate

Targets <u>limited regions</u> of the diseased myocardium involved in the initiation and maintenance of VT.

J Am Coll Cardiol EP 2018;4:307–15

Decrement Evoked Potentials (DeEP)



DEEP potentials maps, identifying a much more circumscribed area of the LV during S1/S2 pacing thus providing a more accurate delineation of the VT circuit than LP map.

DEEP-EGM(*) that accurately colocalizes with the area of the isthmus of VT identified on the LAT map

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J Am Coll Cardiol EP 2018;4:307–15

Conclusion

1. Substrate mapping is indicated for VTs w multiple, changing morphology, HD unstable VTs, or to improve results of catheter ablation.
2. Use of multi-electrode mapping catheter is crucial.
3. In addition to conventional voltage map, additional functional mapping strategy (ILAM, DeEP) may help guide 'targeted' ablation.

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