



Determining VT circuit & successful ablation site; Entrainment pacing & pace mapping

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Disclosure

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How to define the VT Circuit

1. Localization of VT exit site (ECG of VT)
2. Localization of VT substrate (Echo, CT, MRI)
3. Electrophysiologic study
 - ✓ **Substrate mapping**: abnormal signals @ sinus rhythm
 - ✓ **Activation mapping** & **entrainment mapping**
 - ✓ **Pacemapping** during sinus rhythm based on substrate mapping



Agenda

- ❖ Entrainment pacing
- ❖ Pace-mapping



Agenda

- ❖ Overdrive Pacing (ODP)
- ❖ Usage ODP in Diagnosis
- ❖ Entrainment mapping
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Role of overdrive pacing

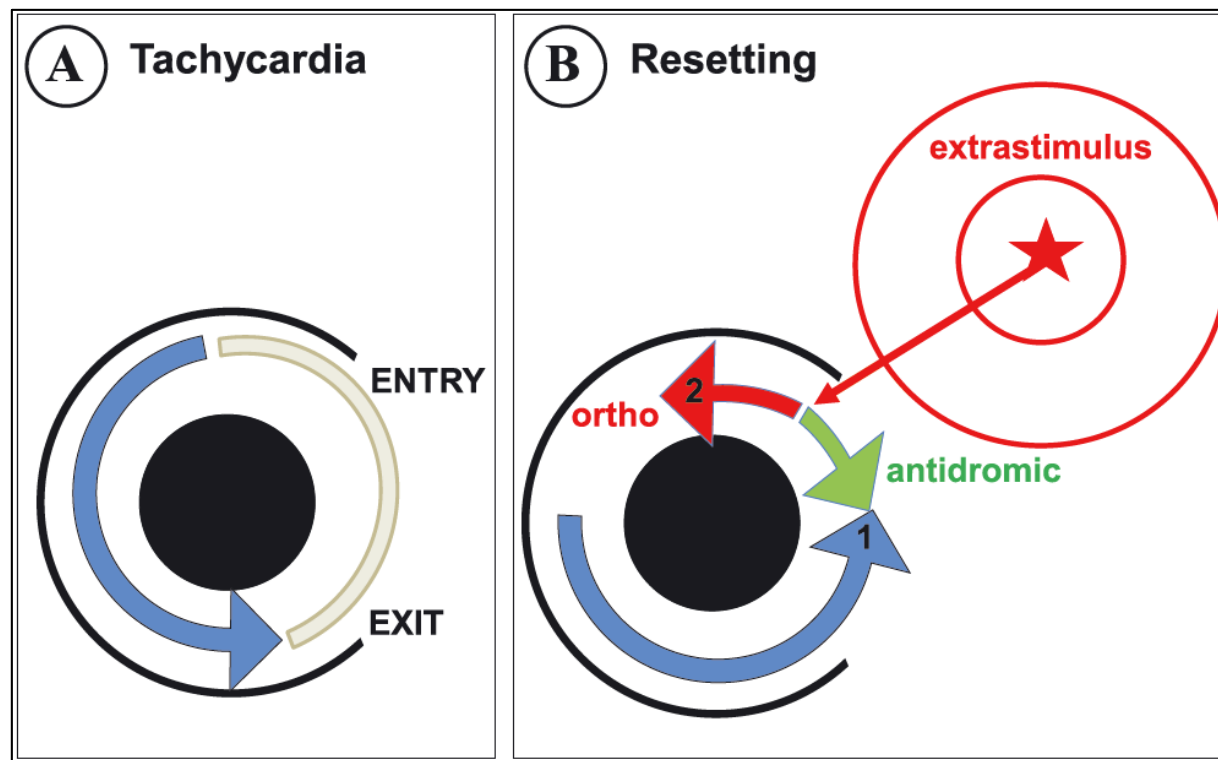
- ❖ Overdrive pacing can aid in choosing target site for ablation
 - ✓ By helping **determine tachycardia mechanism**
 - ✓ By helping **validate putative ablation sites**

- ❖ Ablation target
 - ✓ Focal tachycardia: **presystolic potential** (late diastolic)
 - ✓ Microreentry: **long fragmented diastolic potential**
 - ✓ Macroreentry: **mid-diastolic potential**



What is Resetting?

Changes (advanced/delayed) in timing of a tachycardia cycles as a result of a **premature stimulus**



What is Entrainment?

- ❖ Continuous resetting of a tachycardia by overdrive pacing, **typically in the presence of fusion**
- ❖ Must be differentiated with overdrive suppression: **resetting (+) but fusion (-): focal tachycardia**



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- ❖ Overdrive Pacing (ODP)
- ❖ Usage ODP in Diagnosis
- ❖ Entrainment mapping
- ❖ Pace-mapping



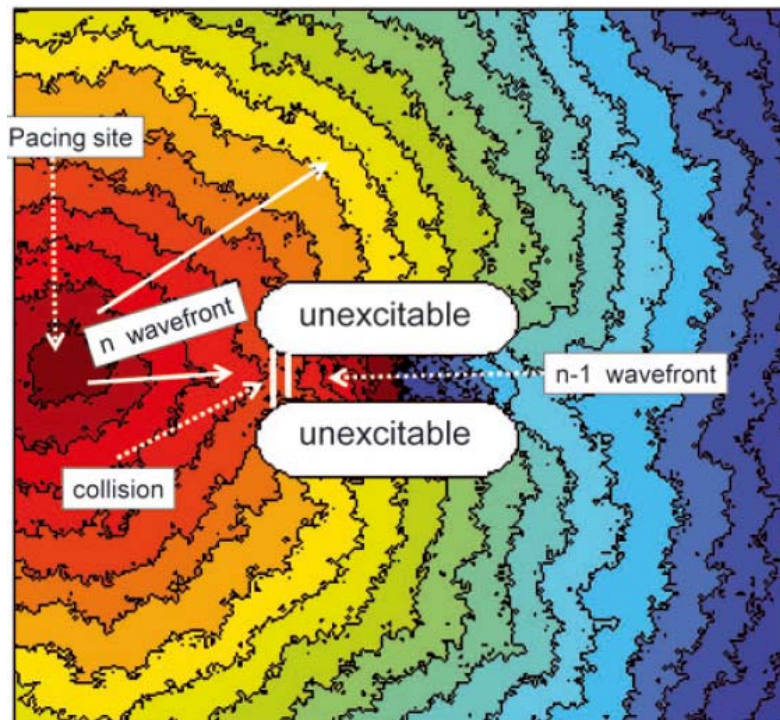
How to do overdrive pacing?

- ❖ Start with stable tachycardia
- ❖ **Decide the site to pace**
 - ✓ RB VT – RV, LB VT – LV/RVOT
 - ✓ to demonstrate the fusion well
- ❖ **Synchronize** to the signal of pacing catheter
- ❖ ODP at a rate of **10~30 msec faster** than tachycardia CL
- ❖ ODP **until all QRS morphologies become constant & accelerated to paced cycle length**
- ❖ Make sure **the same tachycardia resumed**
- ❖ Assess the response to overdrive pacing

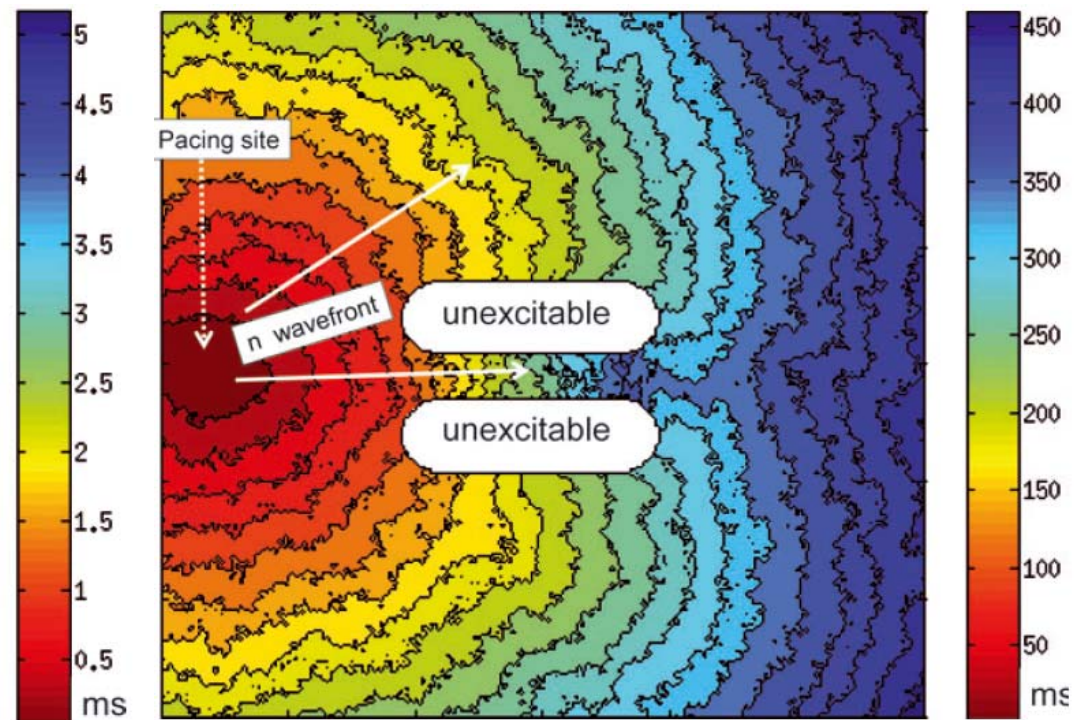


Site of overdrive pacing

Pacing from the **exit site** during **tachycardia**



Pacing from the **same site** during **sinus** rhythm



Responses to overdrive pacing

- ❖ **No capture !!**
- ❖ **Changes in tachycardia**
 - Change to a different circuit
 - Change to a different exit from the same circuit
 - Acceleration
- ❖ **Termination**
- ❖ **Entrainment**



Criteria for the Entrainment

1. **Fusion** must be demonstrated
2. **Precondition:** Resumption of the same **tachycardia** following cessation of pacing, with the first post-pacing complex displaying no fusion but occurring at a return cycle equal to the pacing CL



ENTRAINMENT

To declare entrainment is present, **fusion must be unequivocally demonstrated (except, microreentry)**

❖ **FUSION** is **NOT**

- ✓ Mere capture with overdrive pacing
- ✓ Overdrive pacing followed by tachycardia termination
- ✓ Overdrive pacing followed by change in tachycardia



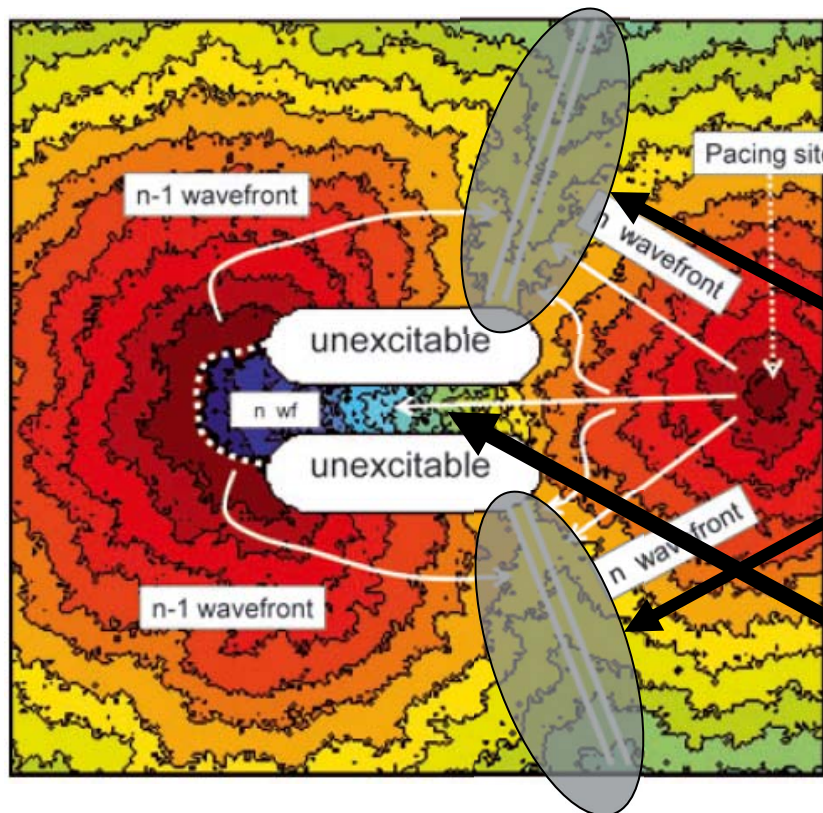
ENTRAINMENT

- ❖ **FUSION** is **PRESENT** when
 - ✓ A clear **blend of fully paced + full tachycardia** complexes
 - ✓ Observe stimulus artifact after onset of accelerated complex
 - evidence that the tachycardia wavefront have exited from the circuit
 - ✓ **Progressive fusion**: Show graded change in activation at different paced rates



FUSION

- **Simultaneous activation** of the atria or ventricles **by two wavefronts**
- Two wavefronts ($n - 1$ & n) activate the same chamber at the same time



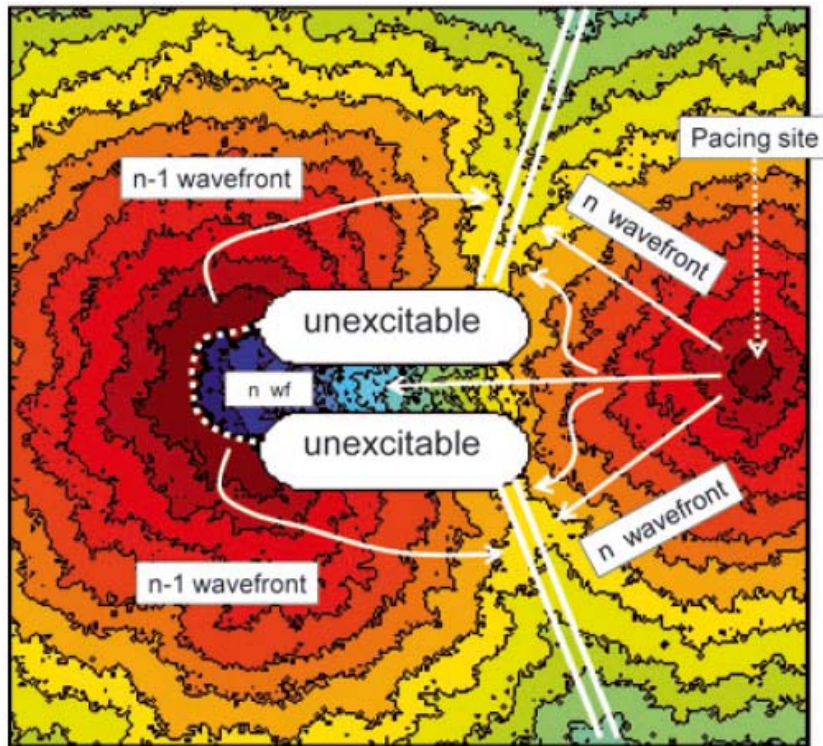
Antidromic propagation
Wavefronts collided & perished

Orthodromic propagation
Penetrated the circuit & continuous reset

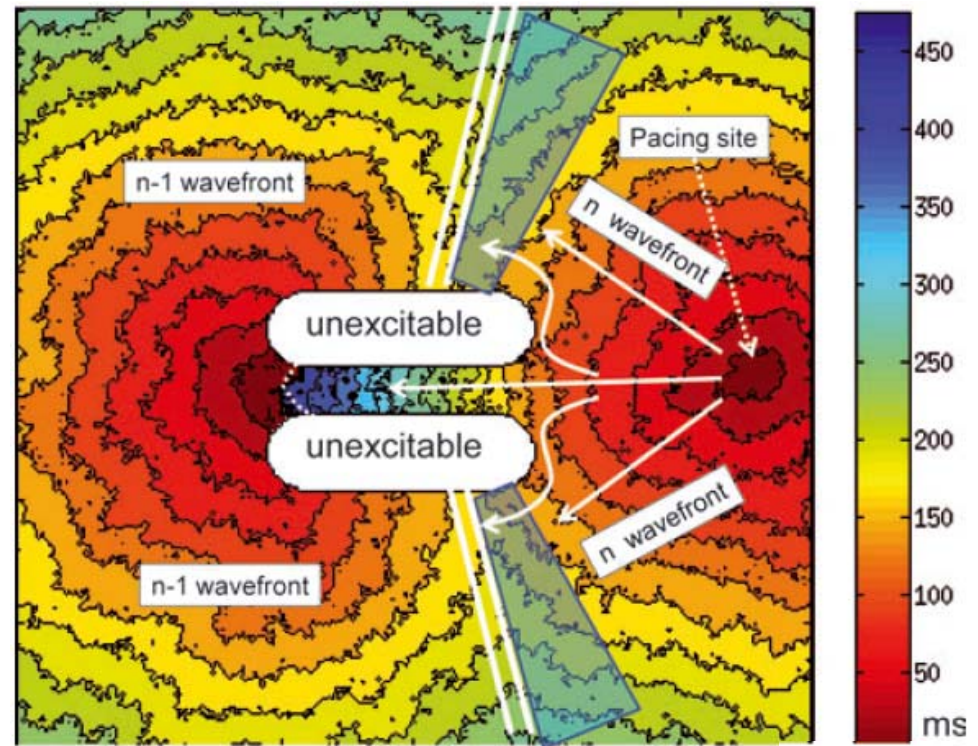


PROGRESSIVE FUSION

Graded change in activation @ different paced rates



450 msec Overdrive pacing



350 msec Overdrive pacing



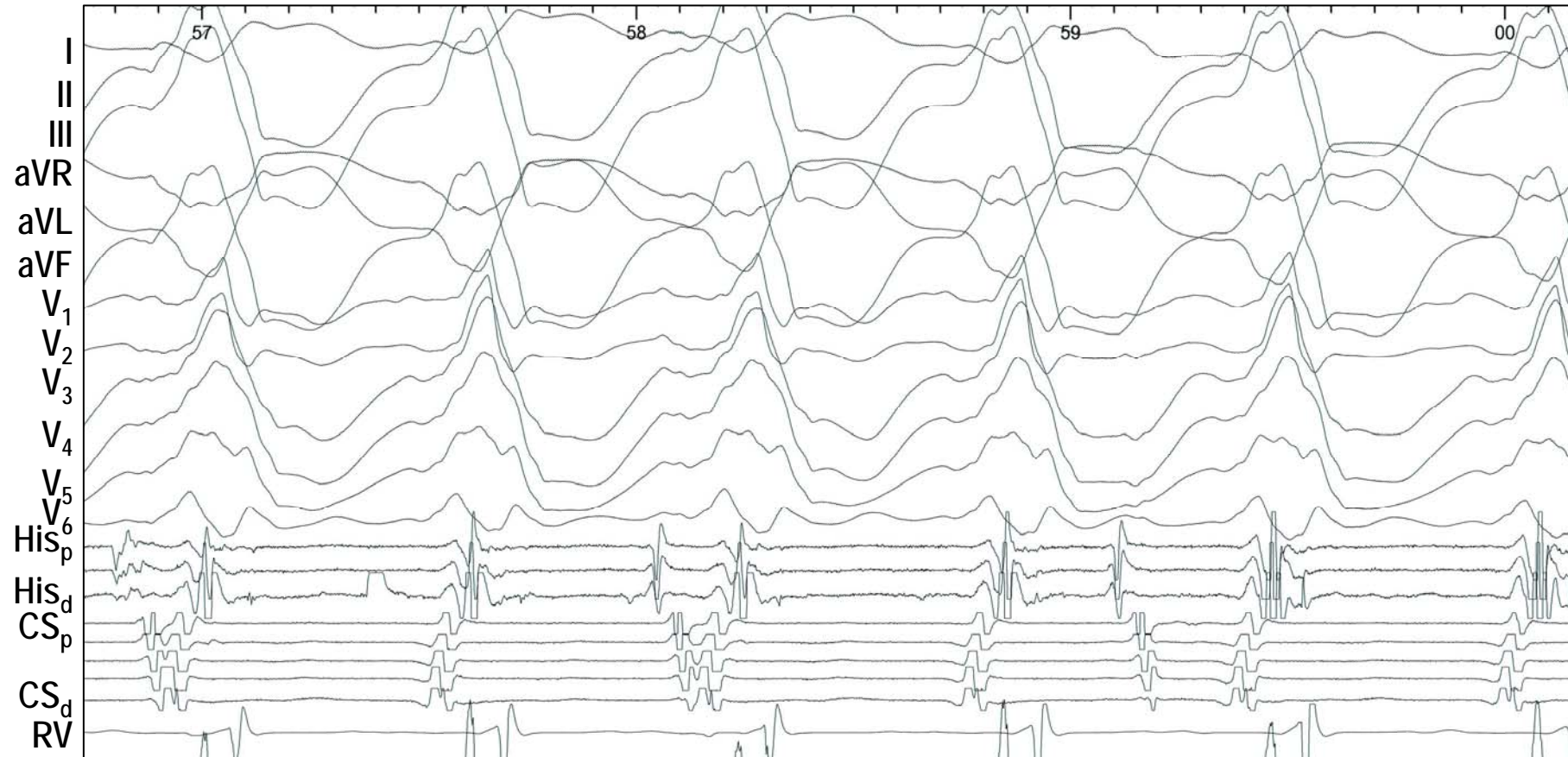
How can we see the fusion of wavefronts?

- ❖ Ventricular tachycardia (VT)
 - ✓ *QRS complex on the surface ECG*

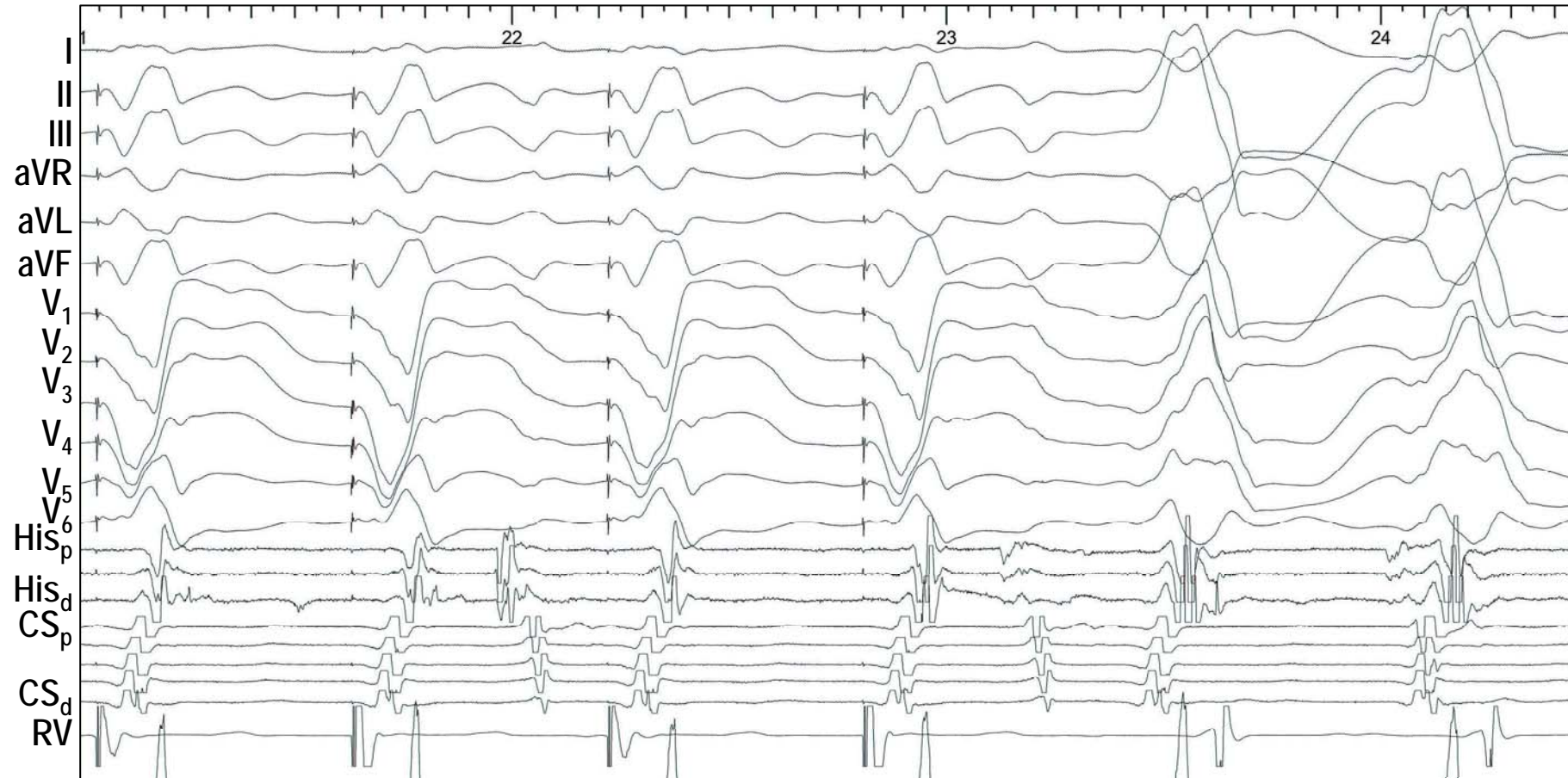
- ❖ Atrial tachyarrhythmia
 - ✓ *P wave on the surface ECG*
 - Hard to use due to T wave or prior ablation/scar
 - ✓ *Intracardiac electrograms: mainstay*

66 YO gentleman with ICM & NICM

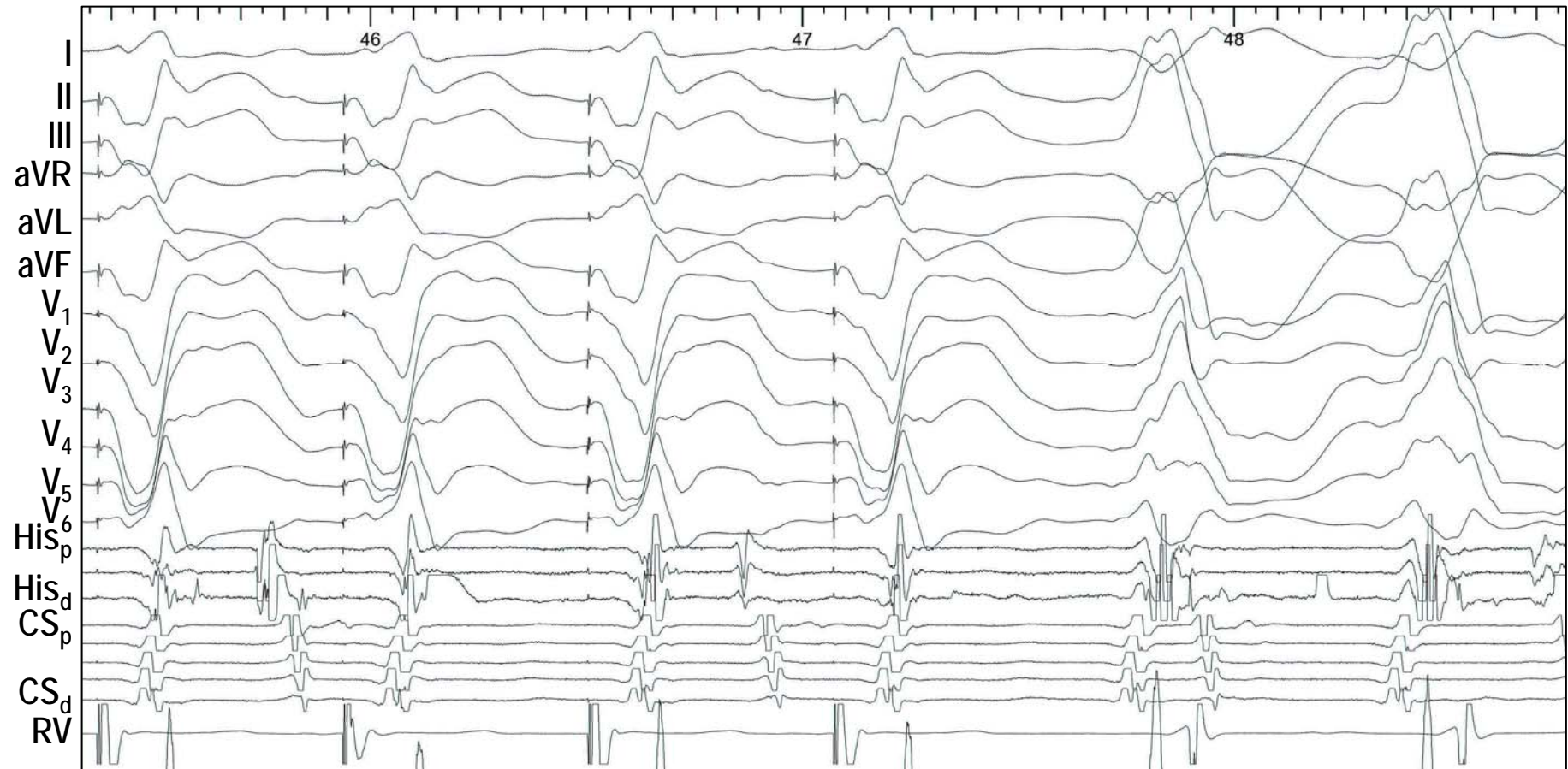
TCL: 605 msec



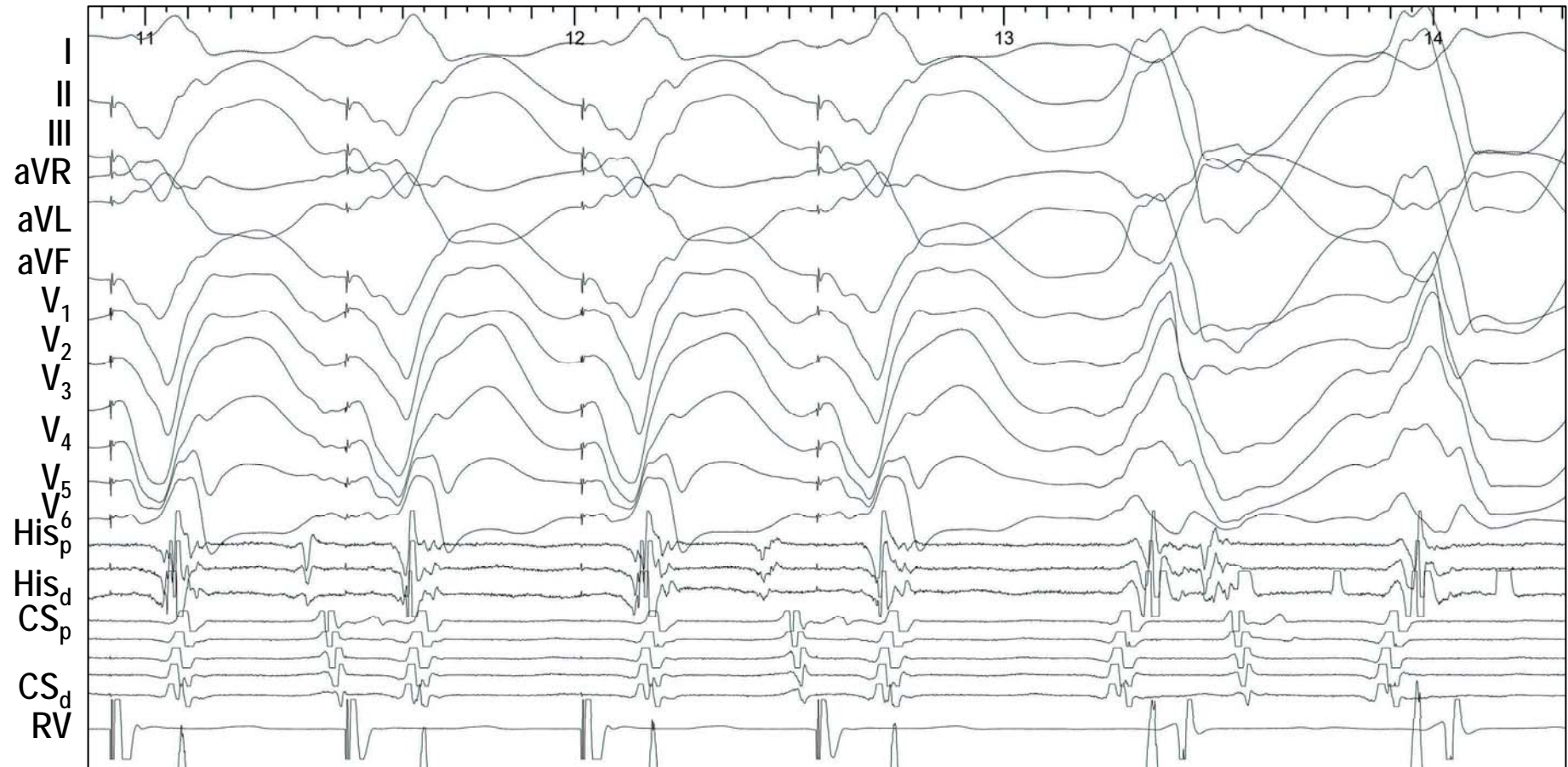
Overdrive pacing with **590 msec**



Overdrive pacing with **570** msec



Overdrive pacing with **550** msec

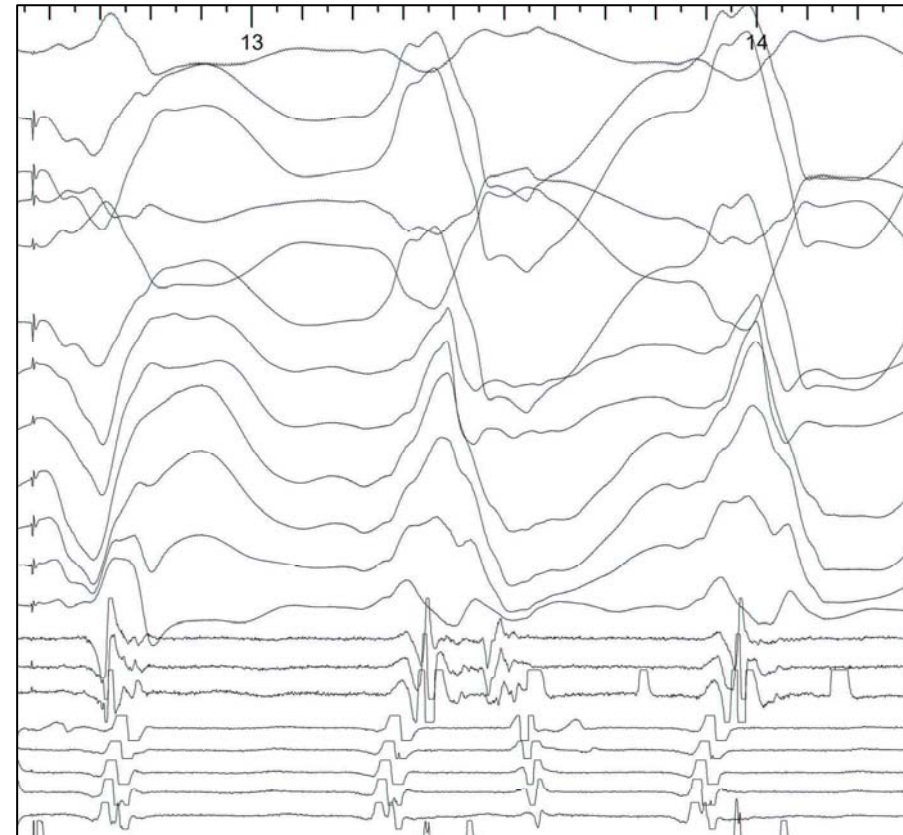
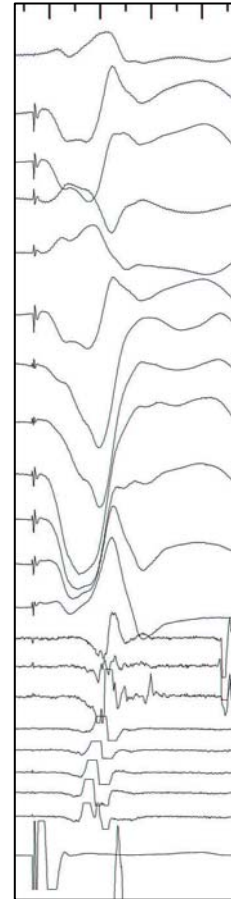
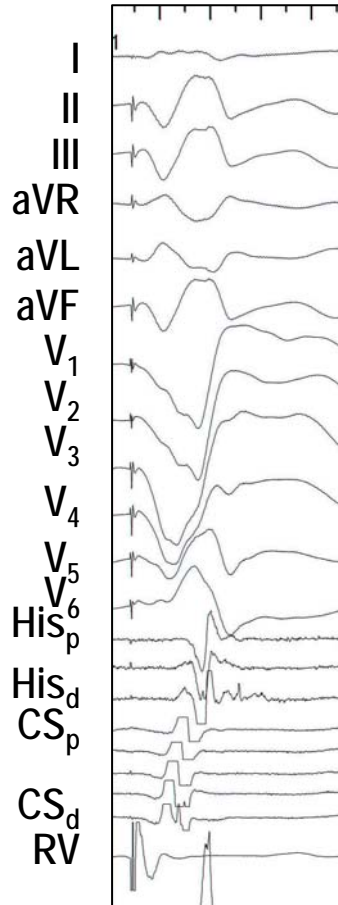


ODP
590ms

ODP
570ms

ODP
550ms

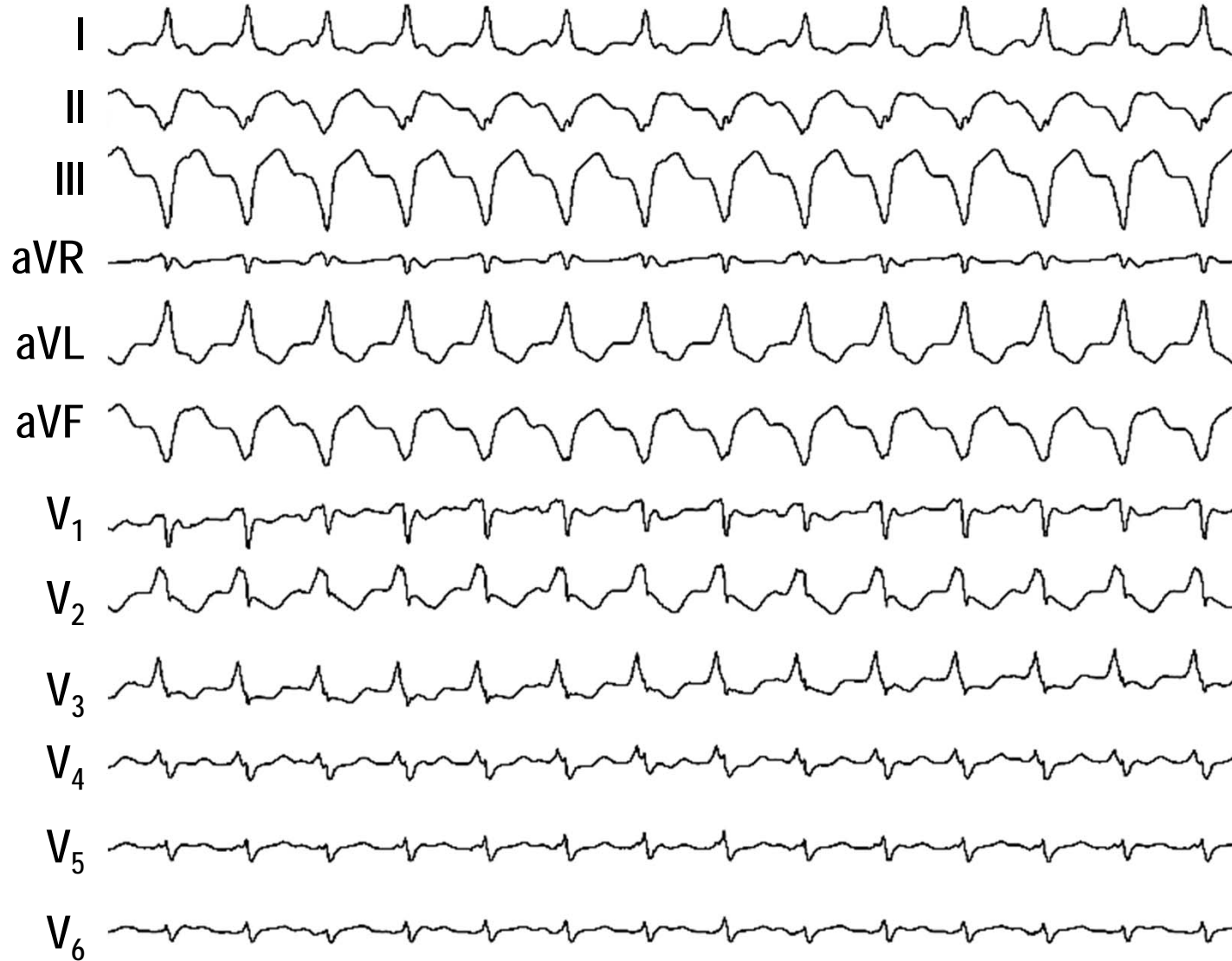
VT



Evidence of *progressive fusion*
∴ Macroreentry



74 YO woman with NICM, CRF on HD, S/P ICD



Overdrive pacing @ RV with 520 msec



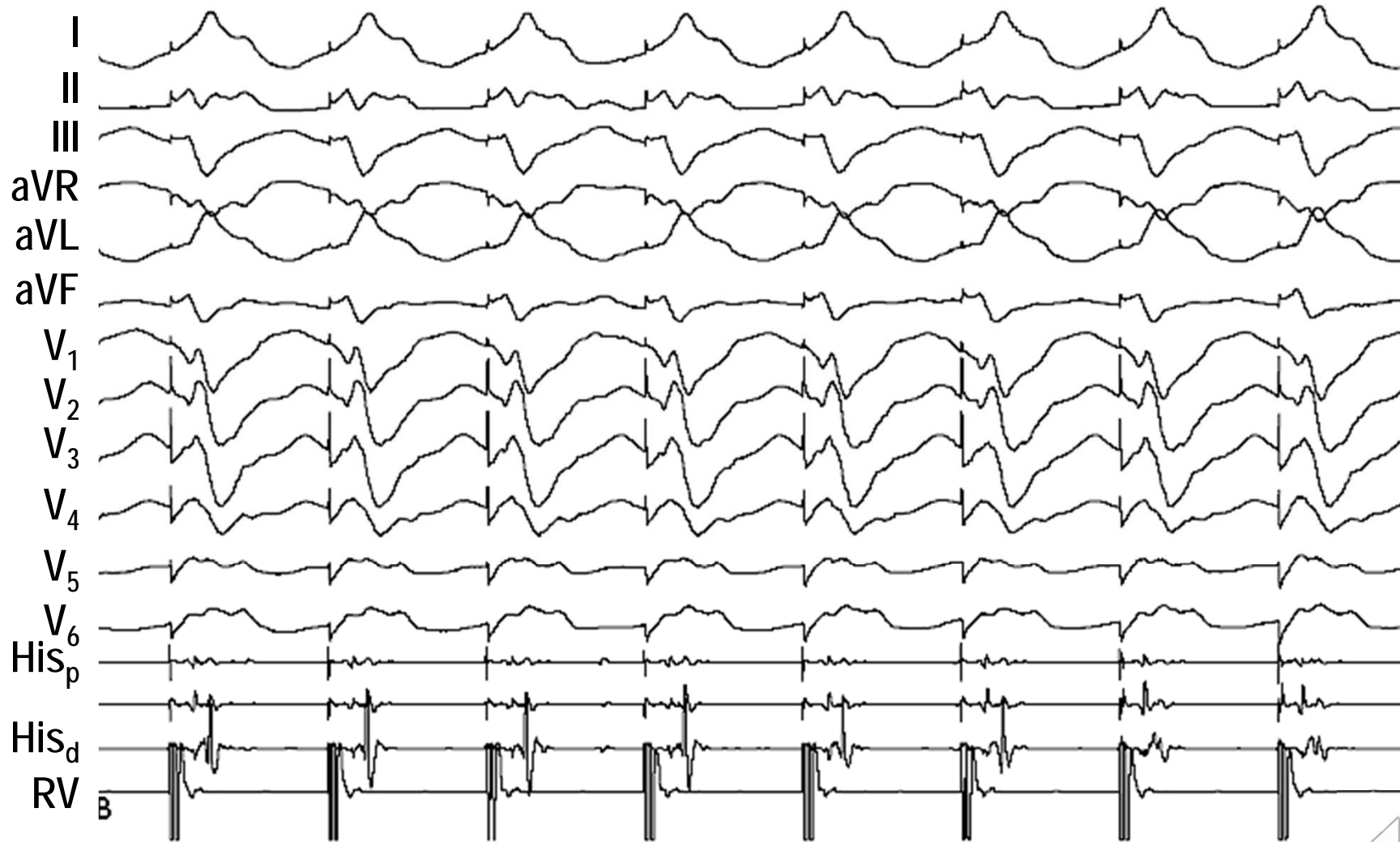
Overdrive pacing @ RV with 490 msec

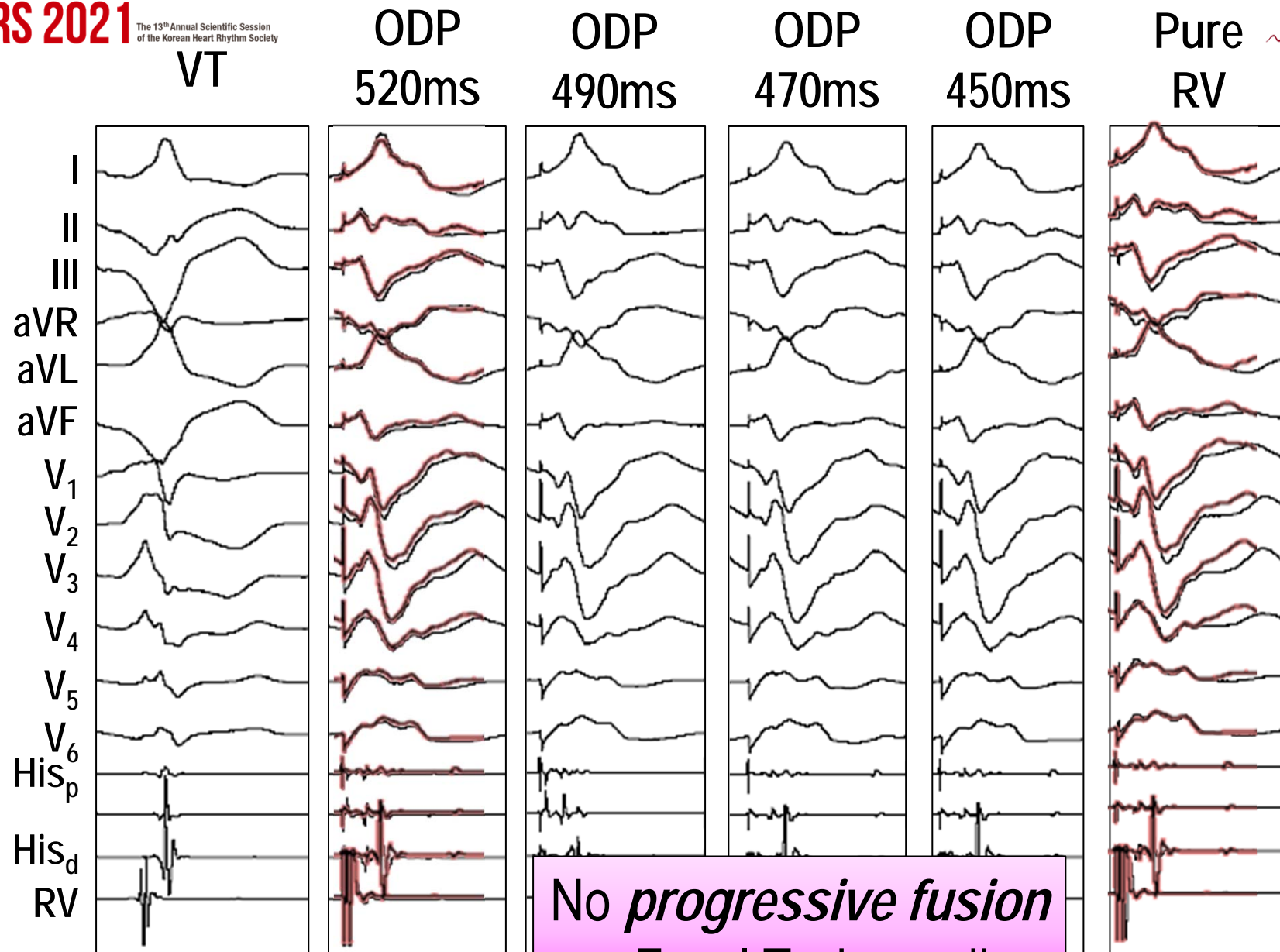


Overdrive pacing @ RV with 470 msec



Overdrive pacing @ RV with 450 msec





450ms

No *progressive fusion*
∴ Focal Tachycardia

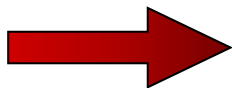
450ms



Responses to overdrive pacing

❖ Lack of fusion

- ✓ Pacing close to the exit of circuit (more antidromic invasion implies less or absent fusion)
- ✓ Fully pacing (focal tachycardia)
- ✓ Decremental conduction inside the circuit



Start to pace from the opposite site of putative VT origin



Agenda

- ❖ Overdrive Pacing (ODP)
- ❖ Usage ODP in Diagnosis
- ❖ **Entrainment mapping**
- ❖ Pace-mapping



Overdrive pacing

- ❖ Simple demonstration of **entrainment alone does not indicate the location** of the pacing site relative to the reentry circuit

- ❖ Other parameters are needed to localize the circuit
 - **Timing of EGM to QRS:** systolic vs. diastolic
 - **QRS configuration** during entrainment
 - **PPI** after entrainment
 - **S-QRS & EGM-QRS** and its relationship to the VT CL



Entrainment Mapping

- ❖ Method to **localize the reentrant circuit and validate the putative ablation target** using timing of mapping point (systolic vs. diastolic), pattern of the fusion (manifest vs. concealed), PPI – TCL, and relationship between stimulation and local electrogram to QRS

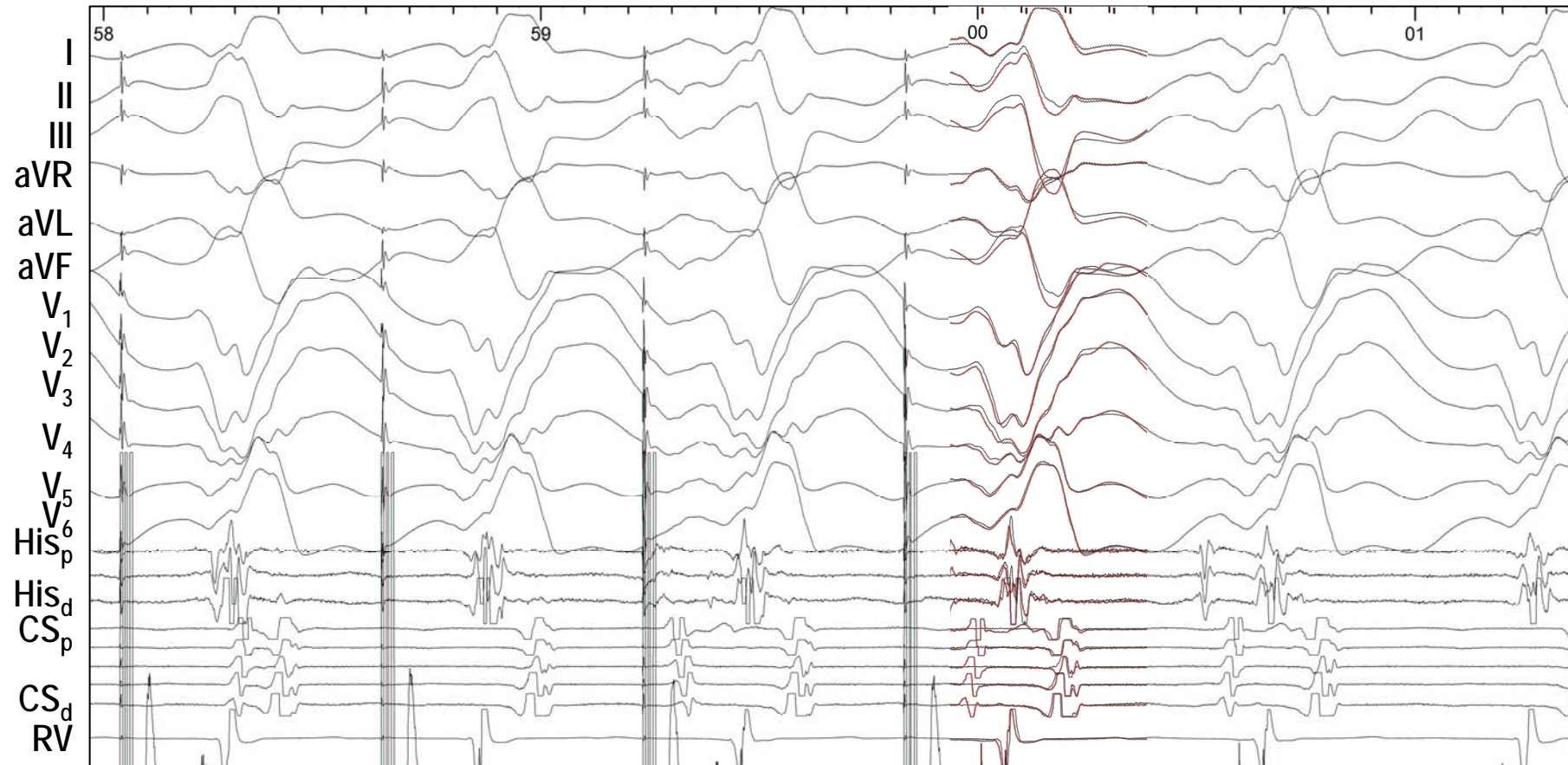


Entrainment Lingo

- ❖ Entrainment with **Manifest fusion**
- ❖ Entrainment with **Concealed fusion**
 - ✓ Other entrainment criteria are met but **no manifest fusion** is seen (pacing looks exactly like tachycardia) due to **pacing in a protected diastolic zone**
 - ✓ **Pacing from the same site during sinus rhythm could produce a different morphology** as long as antidromic conduction through the protected area can occur



Overdrive pacing: **concealed fusion**



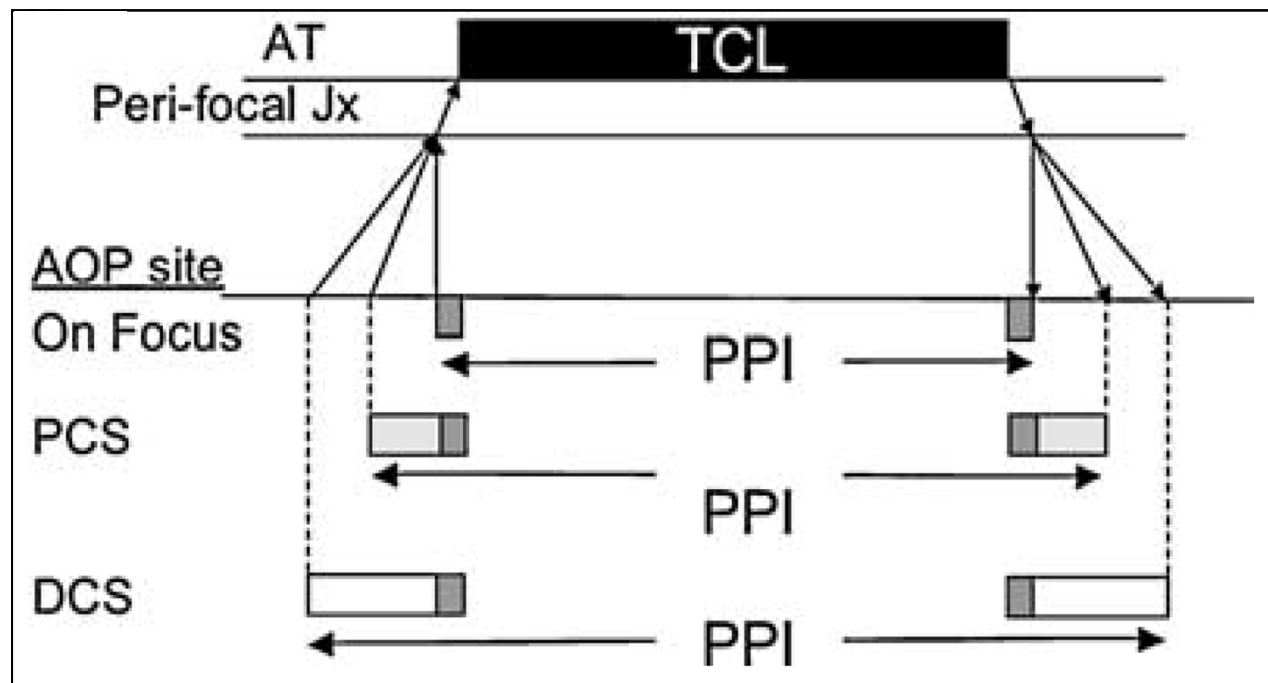
Post-pacing Interval (PPI)

- ❖ Time interval from the last pacing stimulus to the next non-paced recorded electrogram at the pacing site
- ❖ Summation of traveling time of overdrive pacing
Pacing site to the circuit + through the circuit + back to the pacing site
- ❖ **Evaluation of PPI is meaningless when the presence of entrainment has not been established**



A Novel Pacing Maneuver to Localize Focal Atrial Tachycardia

- ❖ PPI-TCL after AOP of a focal AT has a **direct relationship to proximity to the focus**
 - approaches **zero** when pacing from focus



A Novel Pacing Maneuver to Localize Focal Atrial Tachycardia

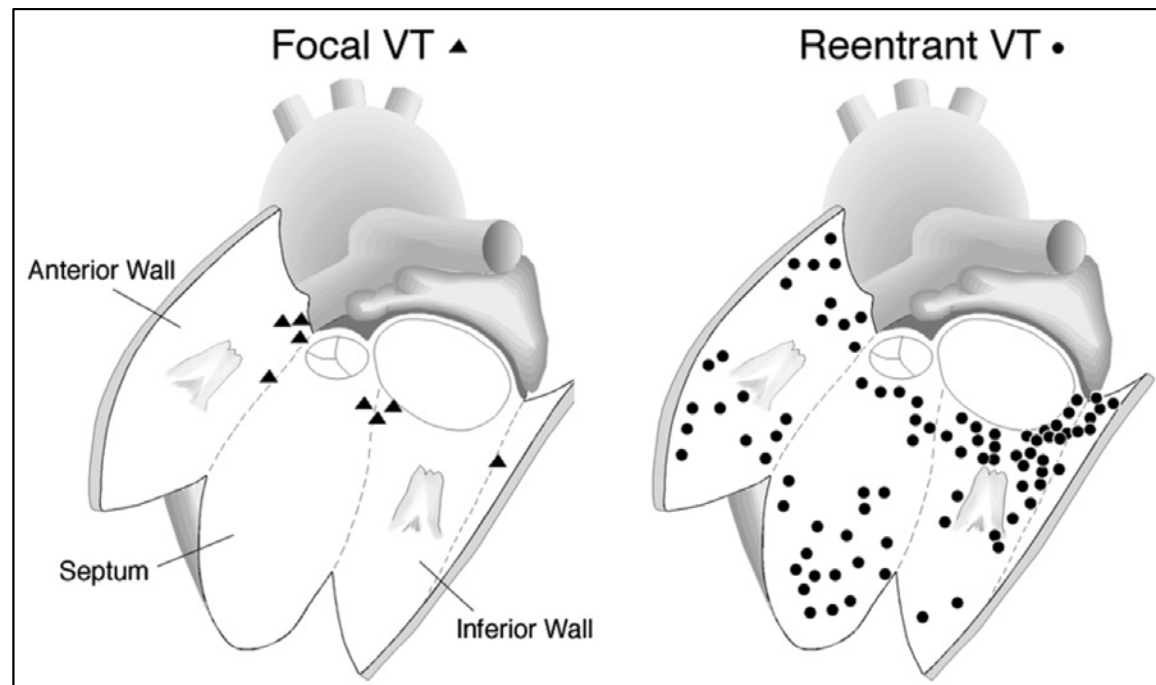
- ❖ PPI-TCL after AOP of a focal AT has a direct relationship to proximity to the focus
→ approaches **zero** when pacing from focus

∴ Merely PPI – TCL \leq 30ms **did not imply** that the tachycardia mechanism is reentry, **nor** the pacing site is on a diastolic corridor



Focal mechanism of ventricular tachycardia in coronary artery disease

- ❖ 46 patients with prior MI (male 89%, age 64.8 ± 10.2 years)
- ❖ 101 VTs were induced (91% macroreentrant VT, 9% focal VT)



Entrainment Mapping

Pacing from the Sites **Outside** the Reentrant Circuit

- Manifest fusion on surface ECG or intracardiac recording, or both
- PPI-TCL > 30 msec
- Stimulus-exit interval > electrogram-exit interval

Pacing from the Sites **Inside** the Reentrant Circuit

- Manifest fusion on surface ECG or intracardiac recording, or both
- PPI-TCL < 30 msec
- Stimulus-exit interval = electrogram-exit interval (\pm 20 msec)

Pacing from a **Protected Isthmus** Inside the Reentrant Circuit

- Concealed fusion
- PPI-TCL < 30 msec
- Stimulus-exit interval = electrogram-exit interval (\pm 20 msec)

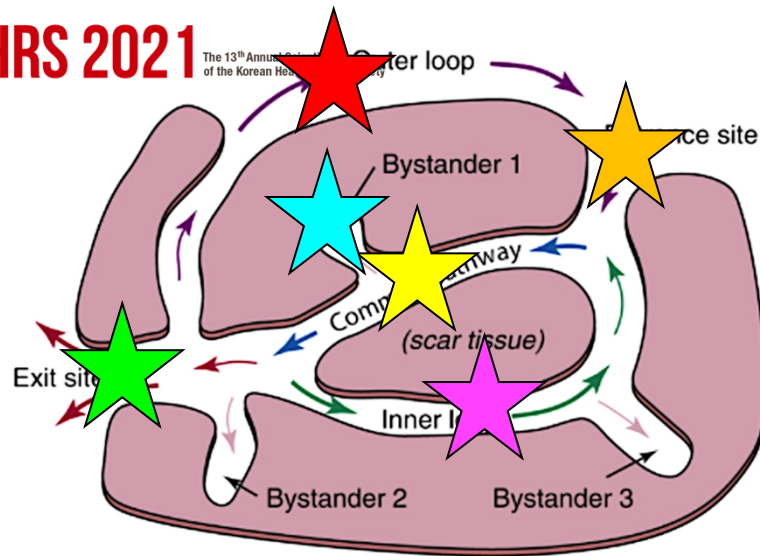


Entrainment Mapping

Entrainment with concealed fusion

- ❖ PPI > TCL : bystander of diastolic corridor
- ❖ PPI \approx TCL : within diastolic corridor
 - ✓ S-EGM < 0.25 X diastolic interval : exit site
 - ✓ S-EGM \approx 0.25 to 0.75 X diastolic interval : mid-corridor
 - ✓ S-EGM > 0.76 X diastolic interval : entrance site



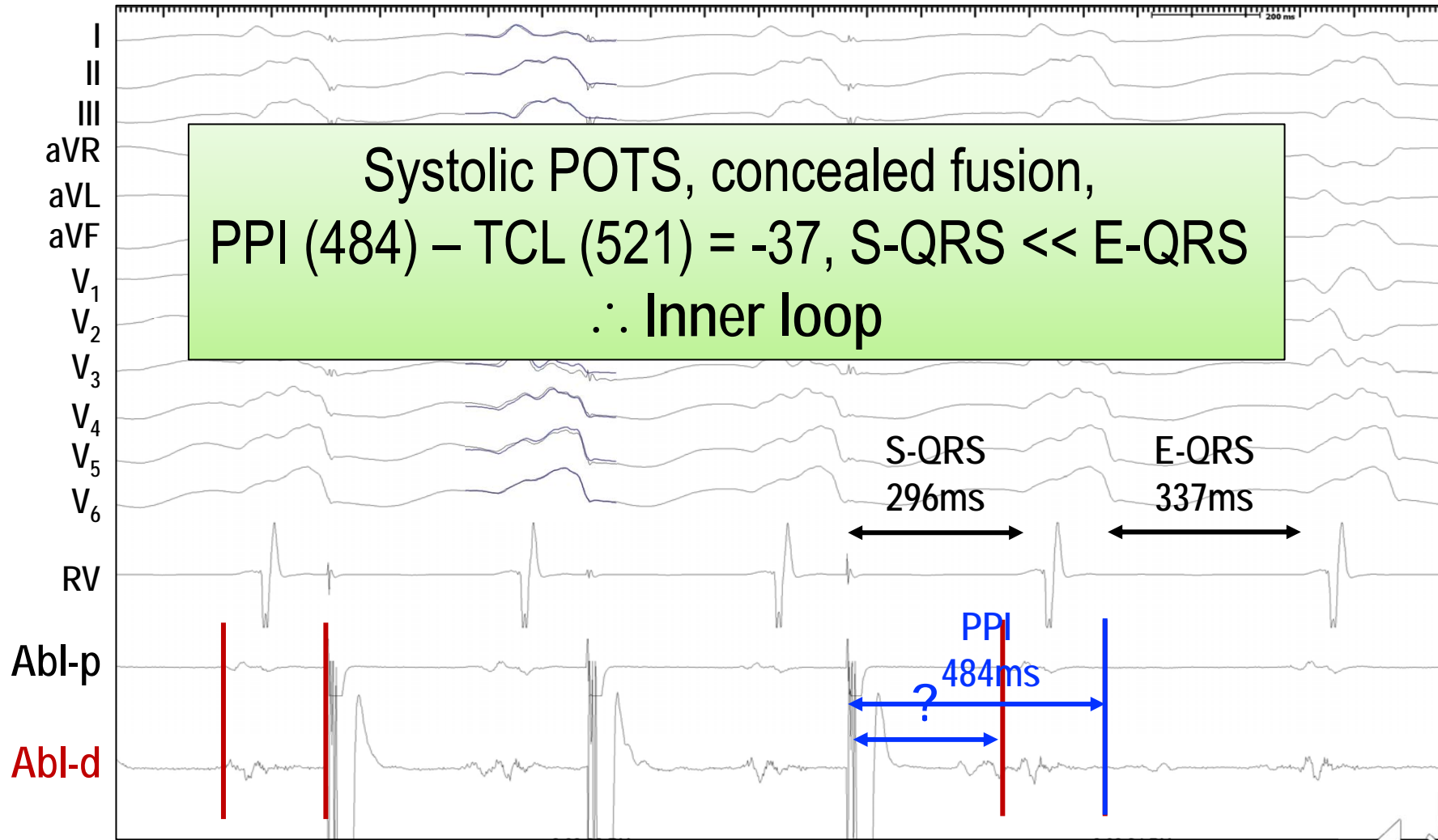


Site of stimulation	Fusion	S-QRS	PPI
Central isthmus	Concealed	= E-QRS in VT (30~70% of TCL)	= TCL
Exit site	Concealed	= E-QRS in VT	= TCL
Entrance site	Concealed	= E-QRS in VT	= TCL
Inner loop	Concealed	< E-QRS in VT	= TCL
Bystander	Concealed	> E-QRS in VT	> TCL
Outer loop	Manifest	< E-QRS in VT	= TCL
Away from the circuit	Manifest	varies	> TCL



Overdrive pacing: **Concealed fusion**

TCL: 521 ms



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- ❖ Usage ODP in Diagnosis
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- ❖ **Pace-mapping**



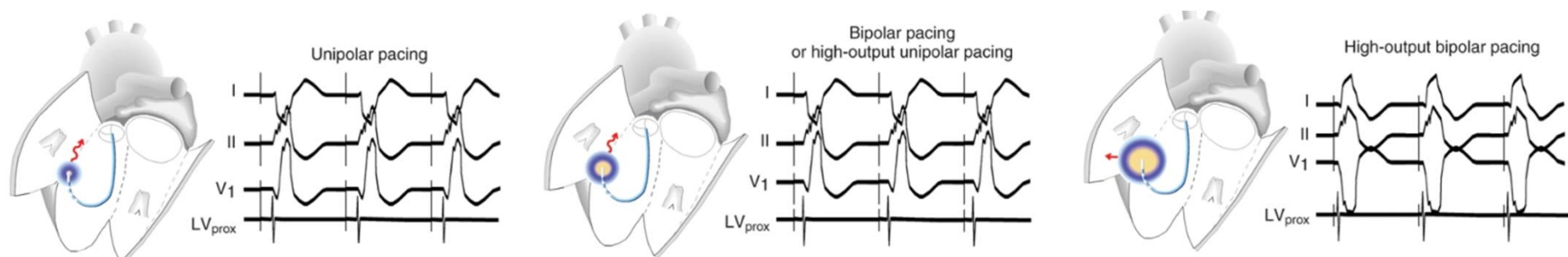
Pace-mapping

- ❖ Used to identify the presumptive exit or isthmus of VT circuit
- ❖ Not sufficient to be the sole guide for ablation
- ❖ Used in conjunction with substrate mapping when other mapping techniques are not feasible



Pace-mapping

- ❖ **Unipolar pacing** (10mA;2ms) **is preferred**
Distal electrode of mapping catheter to IVC electrode
- ❖ **Bipolar pacing**
Smaller artifact; **Possibility of capture@proximal electrode**
- ❖ Pacing with slightly above the capture threshold



Pace-mapping

- ❖ **Comparison of QRS morphology**
 - ✓ Matched QRS: exit or isthmus
 - ✓ Entrance: poor pacemap, typically
- ❖ **S-QRS interval**
 - ✓ S-QRS < 40ms: normal myocardium
 - ✓ Longer S-QRS: conduction delay in the isthmus
 - Ass c/ abnormal long EGM during sinus rhythm
 - ✓ Possibility of bystander site (+)
- ✓ **25%** of reentry circuit sites **have short S-QRS**
- ✓ **> 20%** of long S-QRS sites: **not in the reentry circuit**



Limitations of Pace-mapping during sinus rhythm in Scar-related VT

- ❖ Pacing from close to entrance site results in poor **pace map**; d/t dominant propagation to the antidromic direction of VT
- ❖ Presence of a **functional block** during VT but not during sinus rhythm
- ❖ If, high current is needed: the possibility of far-field capture (+)



Summary

- ❖ Overdrive pacing can help in not only diagnosis but also identifying the ablation target of tachycardia
- ❖ Pace-mapping has several limitations
 - corroborative method of localizing reentrant VT circuit





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Thank you for your attention !

