

Basic principle of entrainment

서울성모병원

박정욱

KHRS, Allied Professional, 2021.06.04

Entrainment mapping

“Transient entrainment of tachycardia as continuous resetting of a reentrant tachycardia to a pacing rate that is faster than the rate of the tachycardia, but which fails to interrupt it”

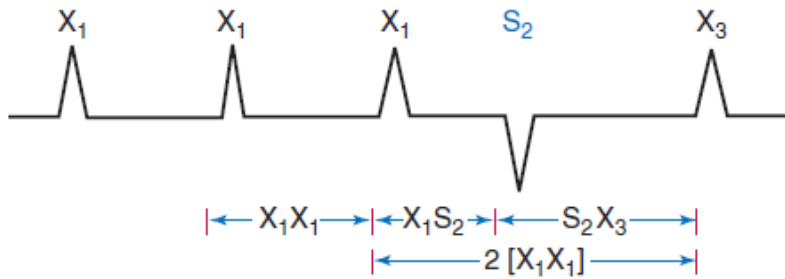
Albert L. Waldo

“Entrainment is a repetitive resetting of the previously reset circuit”

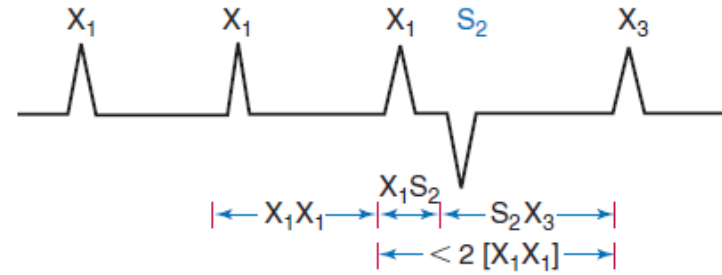
Mark E Josephson

Tachycardia response to resetting

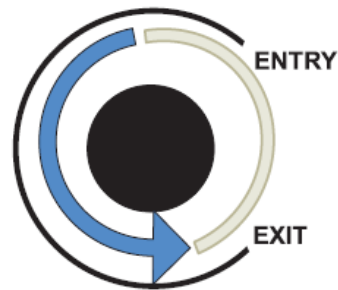
Compensatory pause



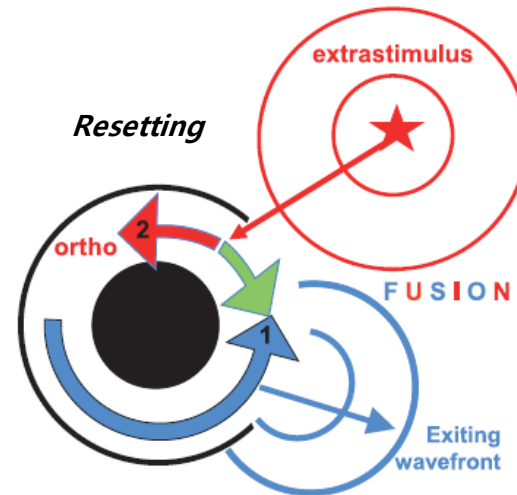
Non-compensatory pause (Resetting)



Reentry



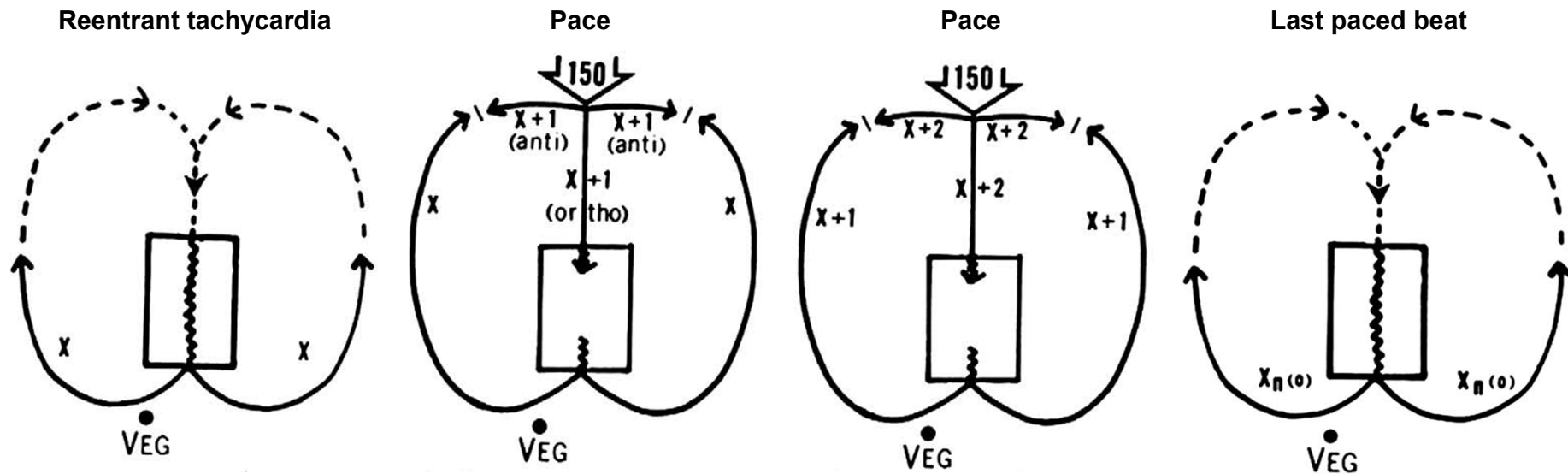
Resetting



Waldo's criterion for entrainment

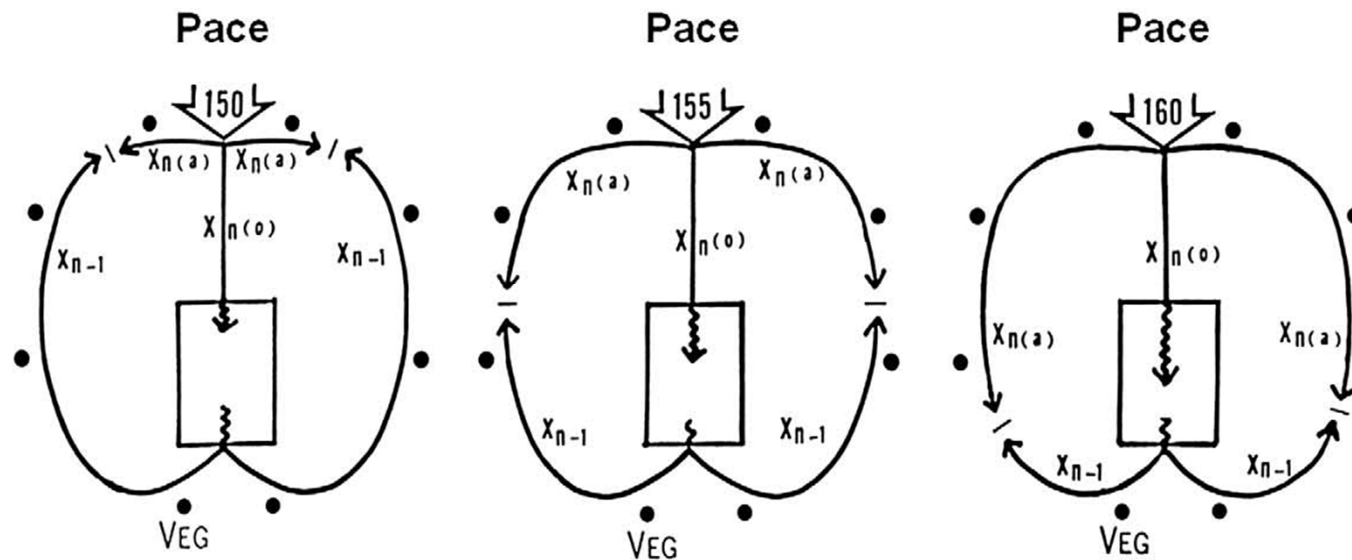
1. During a tachycardia, when pacing at a constant rate that is faster than the rate of tachycardia and which fails to interrupt it, there is the **demonstration of constant fusion beats in the ECG except for the last captured beat, which is not fused**
2. During a tachycardia, when pacing at **two or more constant rates** that are faster than the rate of the tachycardia but which fail to interrupt it, there is the demonstration of constant fusion beats in the ECG at each rate, but **different degrees of constant fusion at each rate**.
3. During a tachycardia, when pacing at a constant rate that is faster than the rate of tachycardia and which **interrupts it, there is the demonstration of localized conduction block to a site or sites for one beat followed by activation of that site or those sites by the next paced beat from a different direction and with a shorter conduction time**.
4. During a tachycardia, when pacing at **two constant rates** that are faster than the rate of tachycardia but which fail to interrupt it, **there is the demonstration of a change in conduction time to and EG morphology at an electrode recording site**

1st criterion (Constant fusion)

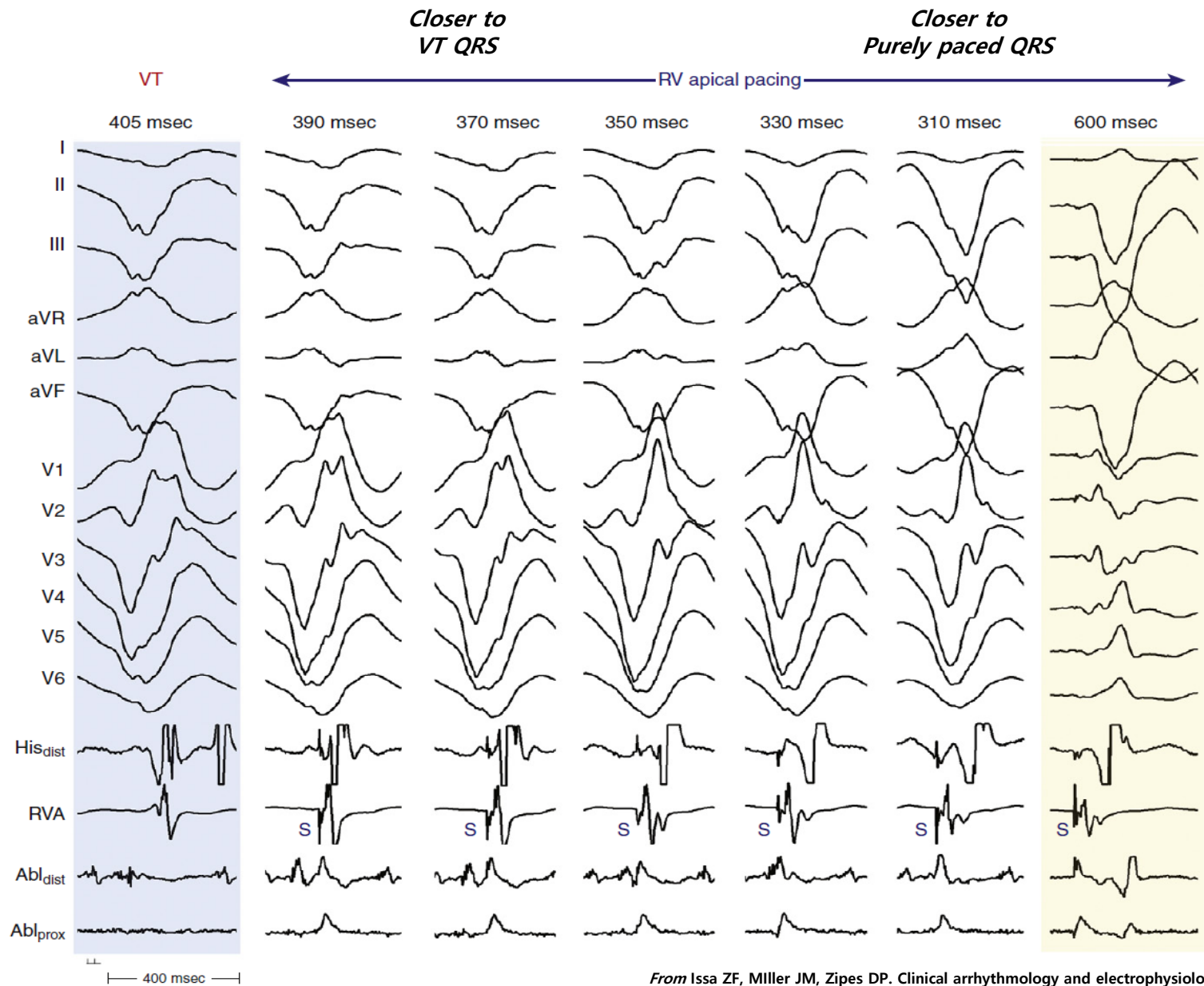


During a tachycardia, when pacing at a constant rate that is faster than the rate of tachycardia and which fails to interrupt it, there is the *demonstration of constant fusion beats in the ECG except for the last captured beat, which is not fused*

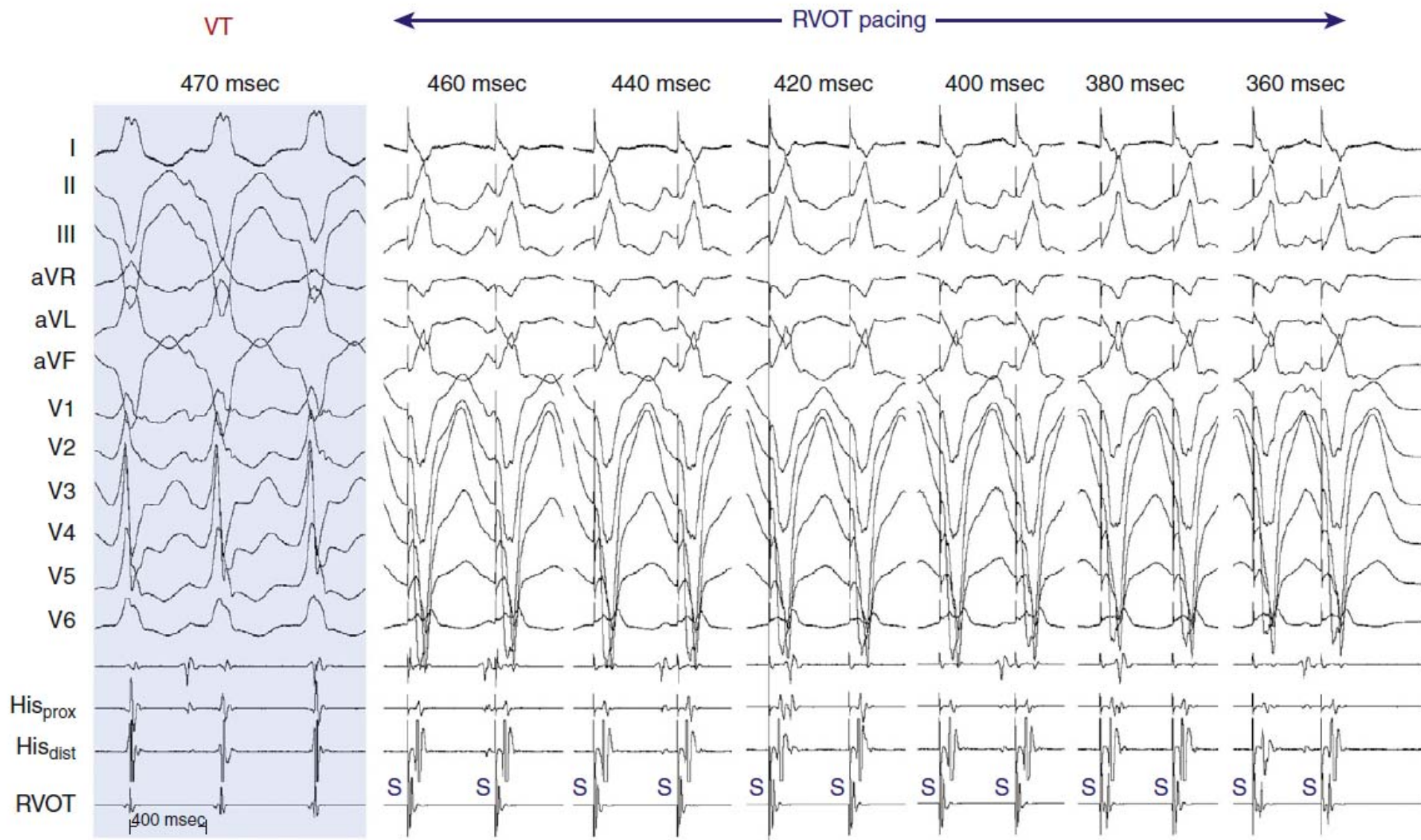
2nd criterion (Progressive fusion)



During a tachycardia, when pacing at *two or more constant rates* that are faster than the rate of the tachycardia but which fail to interrupt it, there is the demonstration of constant fusion beats in the ECG at each rate, but *different degrees of constant fusion at each rate*.

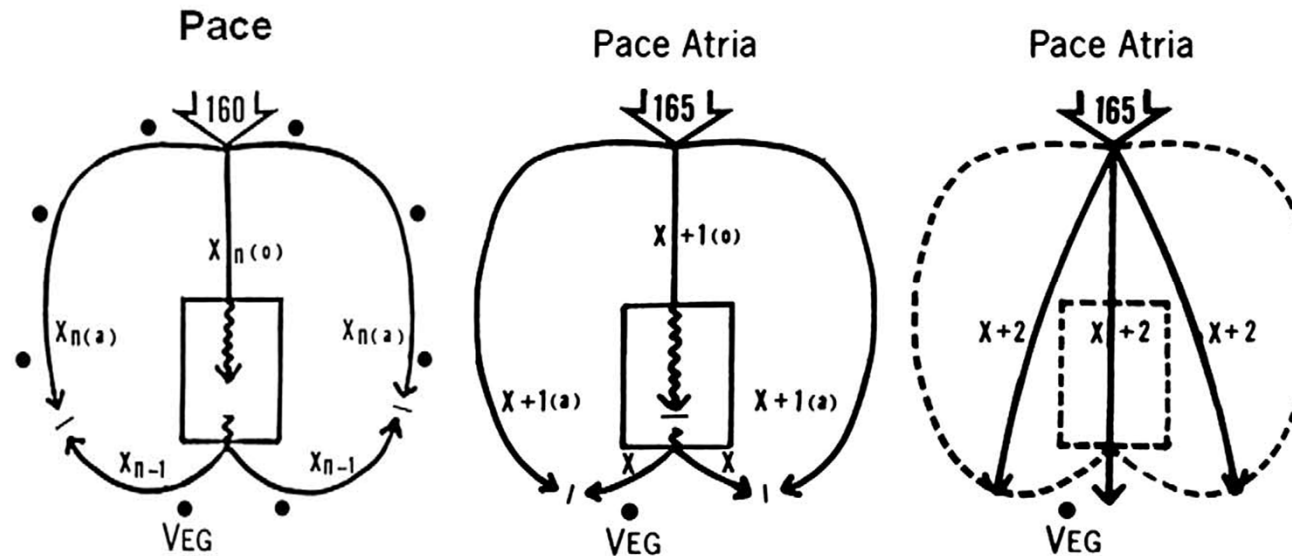


From Issa ZF, Miller JM, Zipes DP. Clinical arrhythmology and electrophysiology 2012



From Issa ZF, Miller JM, Zipes DP. Clinical arrhythmology and electrophysiology 2012

3rd criterion (Interruption of tachycardia)



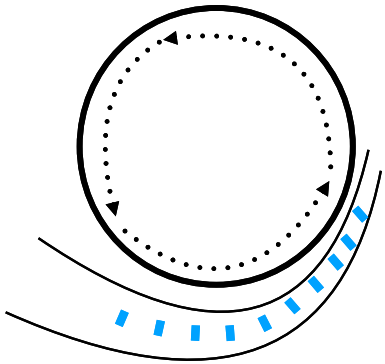
During a tachycardia, when pacing at a constant rate that is faster than the rate of tachycardia and which *interrupts it, there is the demonstration of localized conduction block to a site or sites for one beat followed by activation of that site or those sites by the next paced beat from a different direction and with a shorter conduction time.*

4th criterion (Progressive fusion)

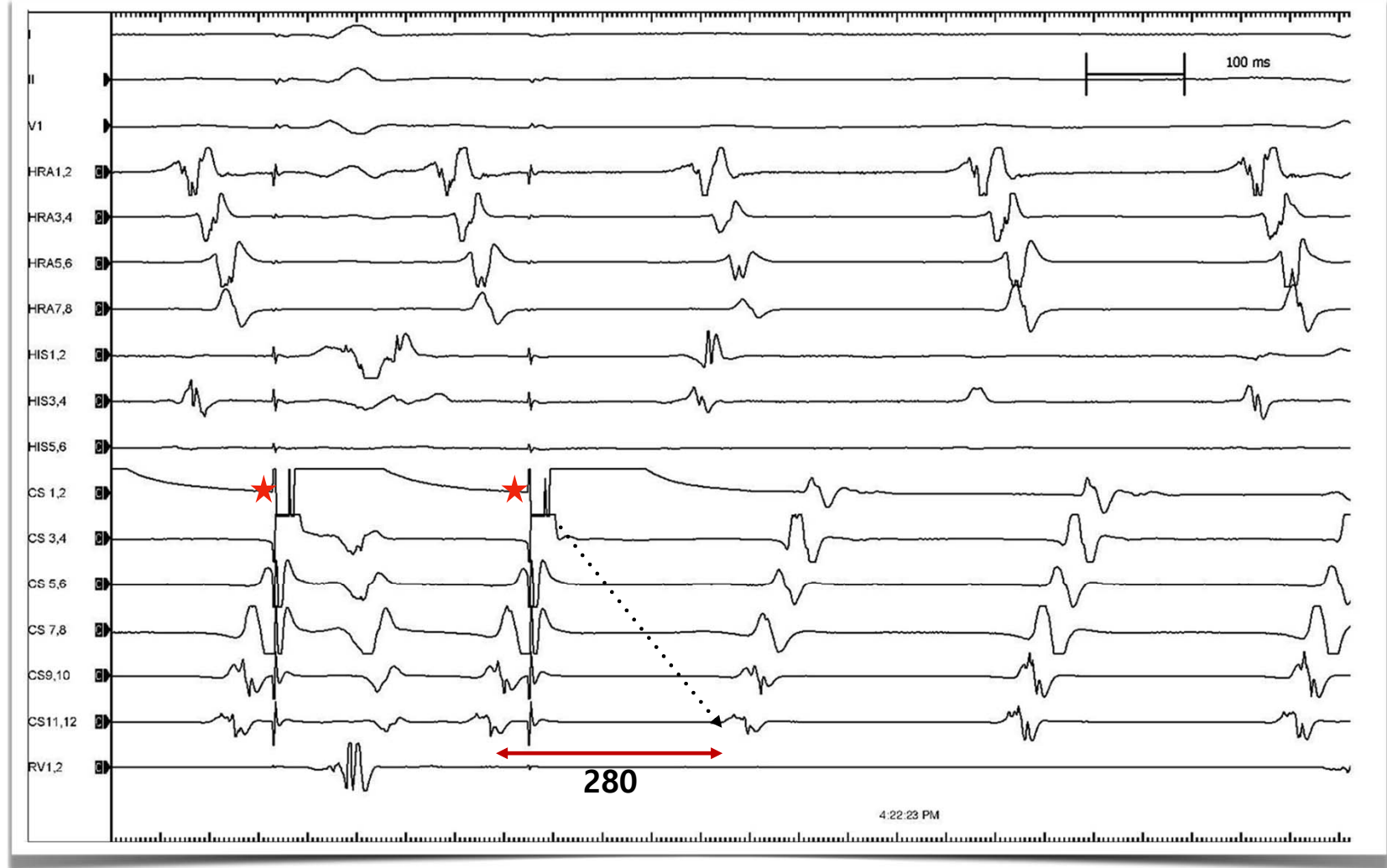
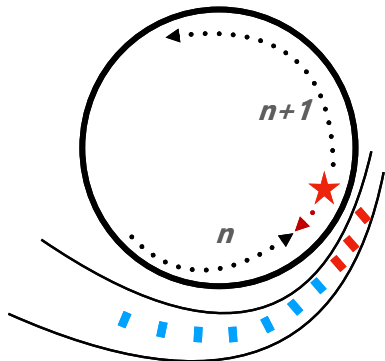
During a tachycardia, when pacing at *two constant rates* that are faster than the rate of tachycardia but which fail to interrupt it, *there is the demonstration of a change in conduction time to and EG morphology at an electrode recording site*

TCL 300 ms, PCL 280 ms

PMI AFL (CCW)

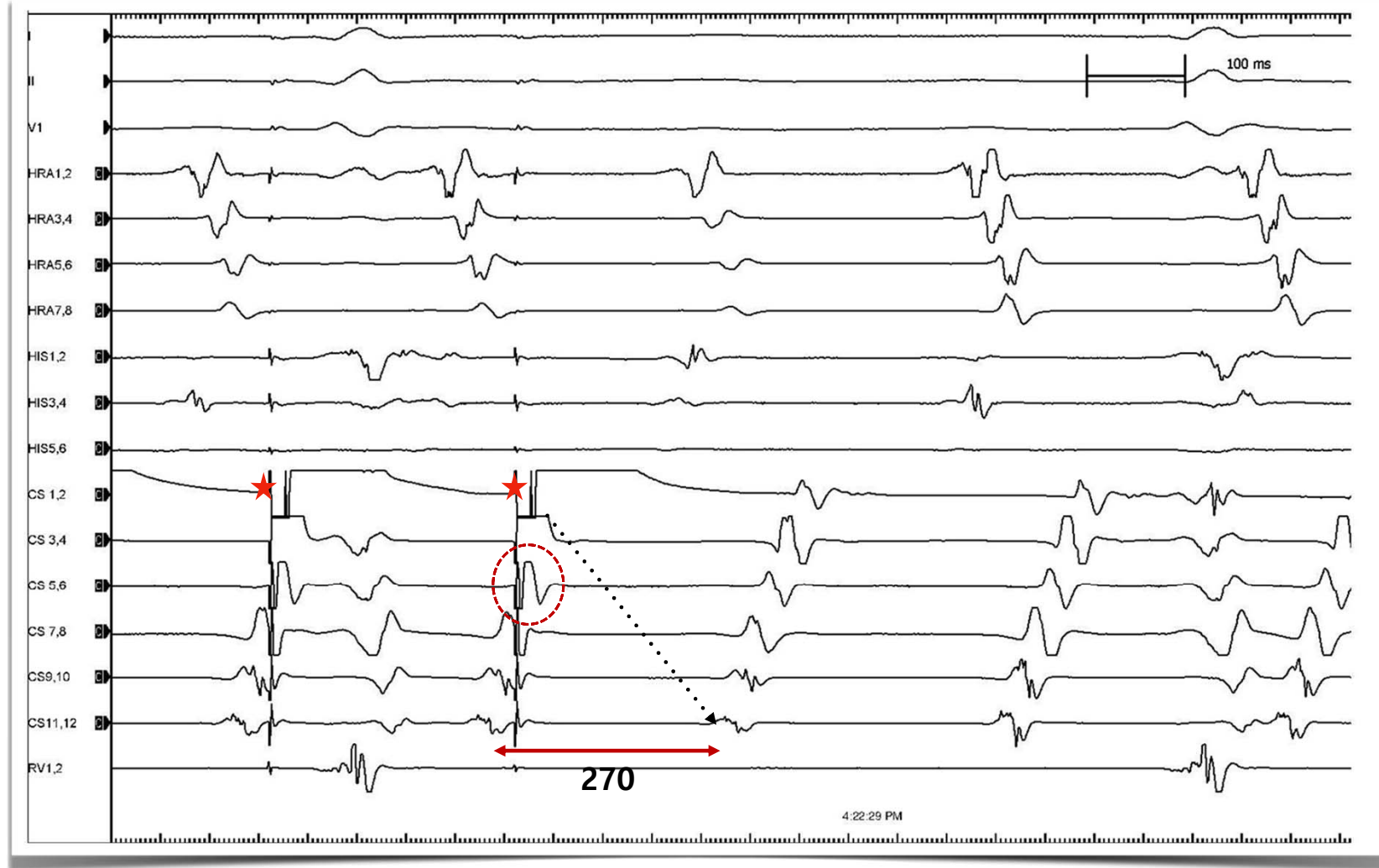
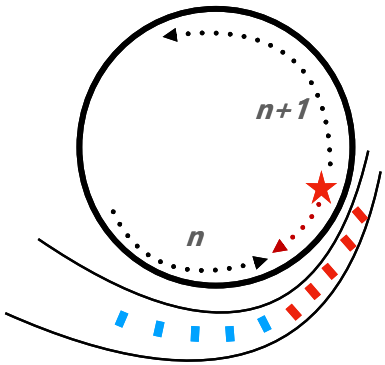


D CS entrainment



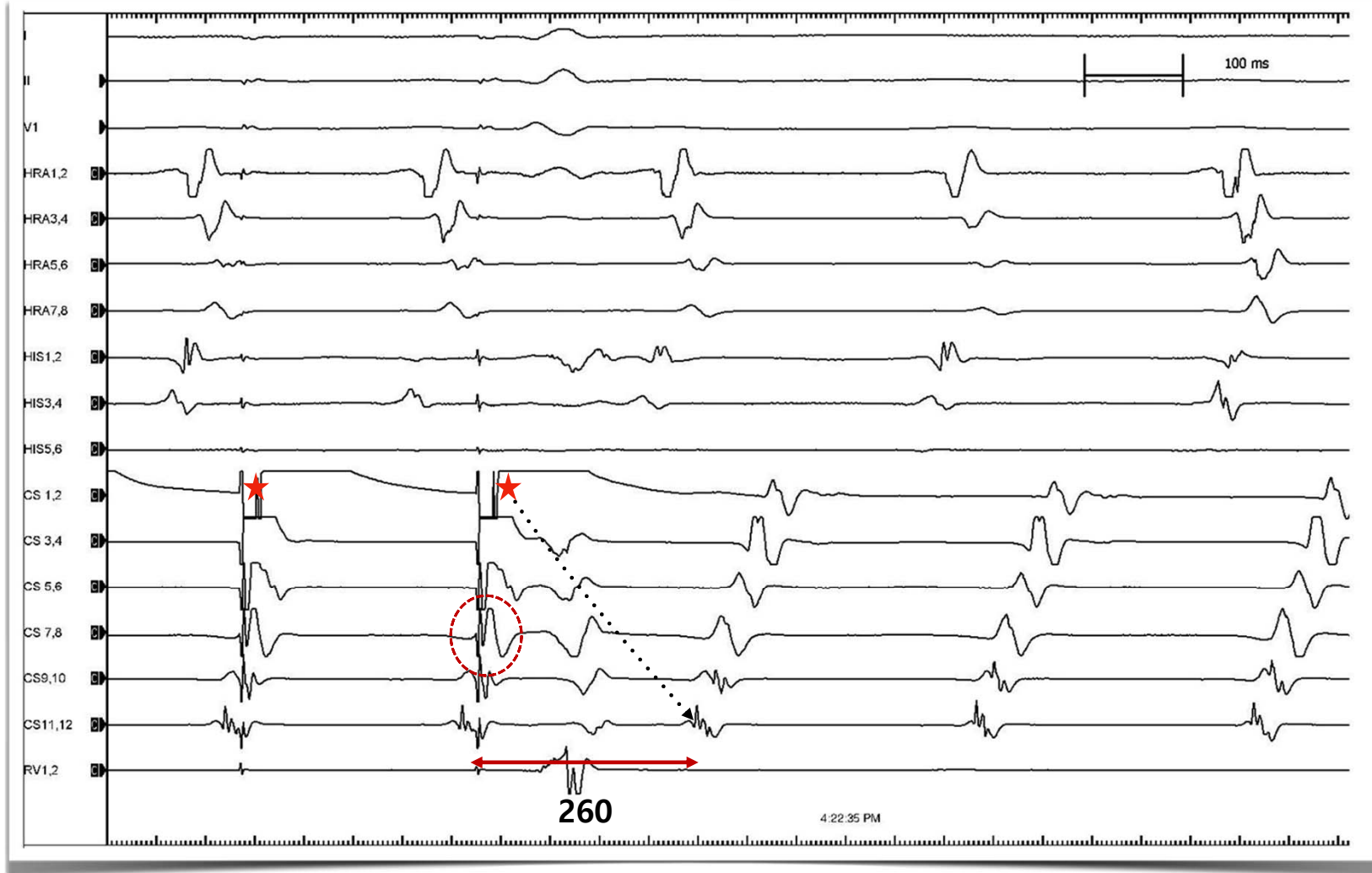
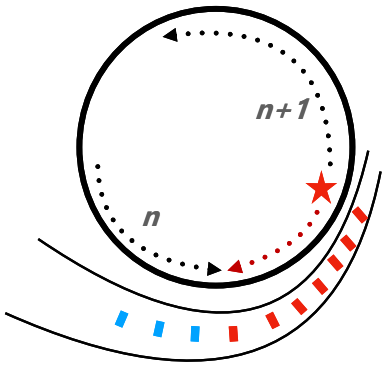
TCL 300 ms, PCL 270 ms

D CS entrainment

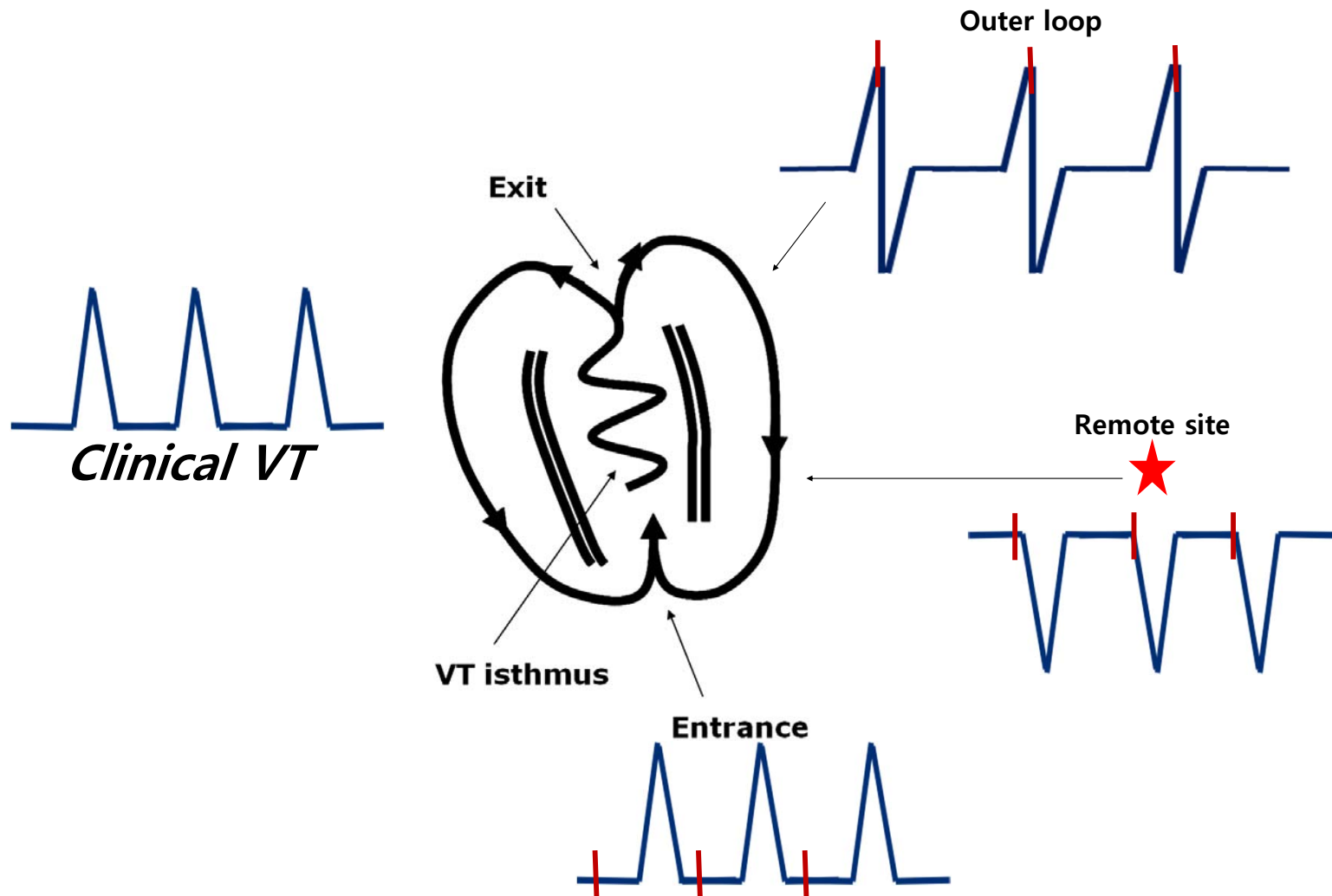


TCL 300 ms, PCL 260 ms

D CS entrainment



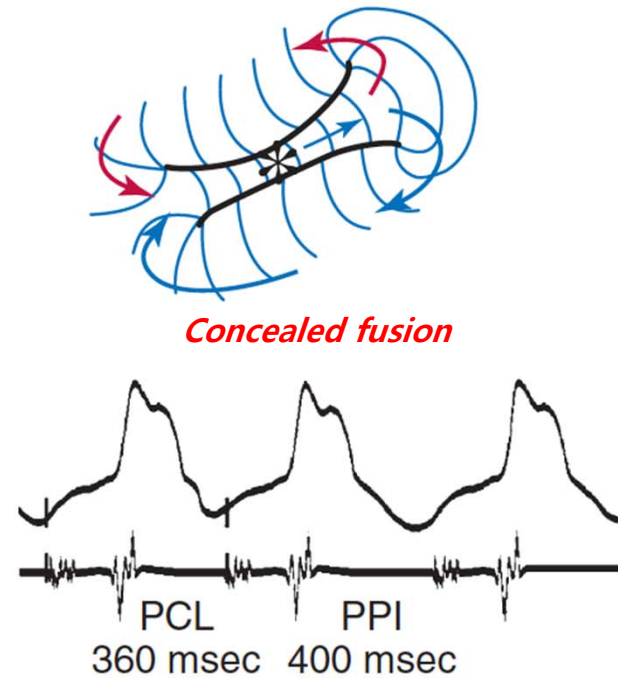
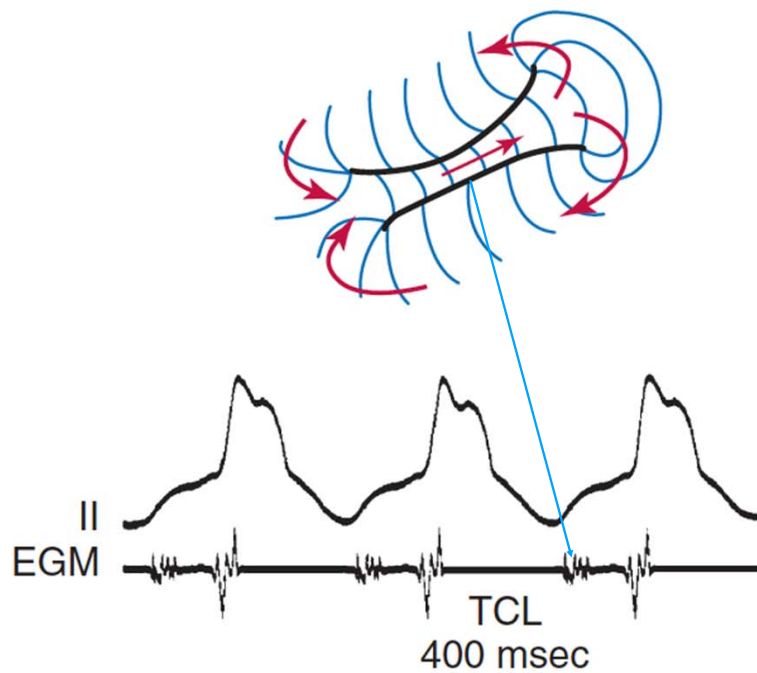
Manifestation of fusion - pacing site dependence



Concealed fusion

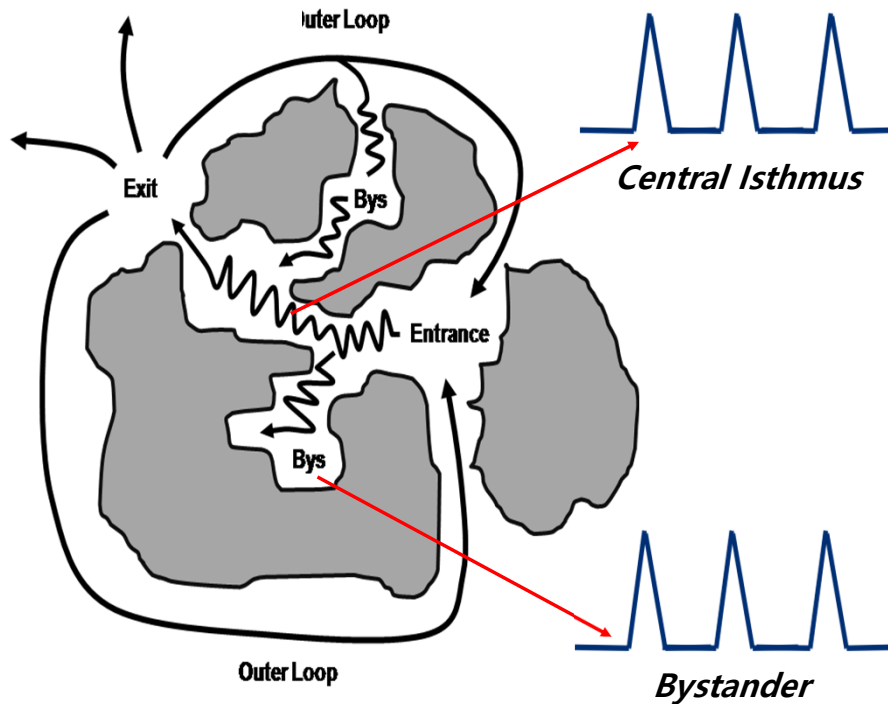
Tachycardia

Entrainment from within circuit (inside central path)



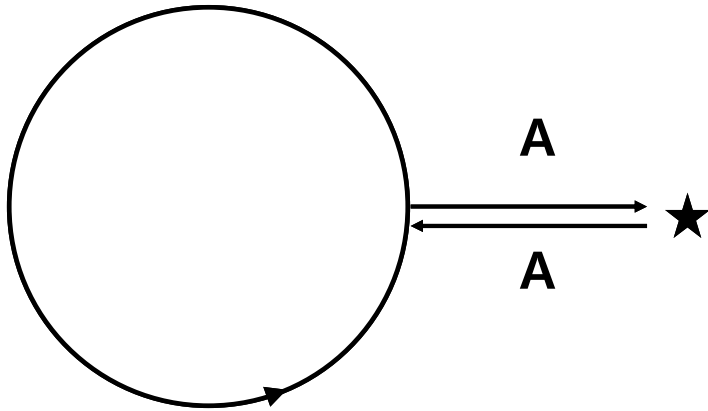
Distinguishing between critical and bystander isthmus

Measurements



- Post pacing interval (PPI)
- Stim to REF - EGM to REF interval
- N+1 difference
- Prematurity
- Needed Numbers to Entrain (NNE)
- Predicted PPI - TCL

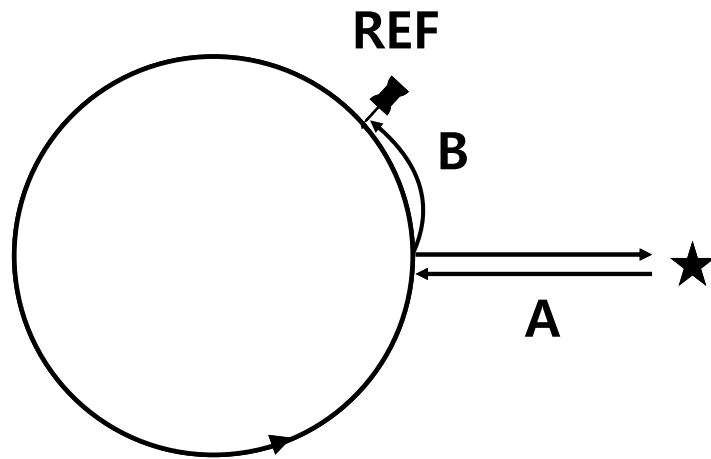
Post pacing interval(PPI)



$$\text{PPI} (\star) = A + \text{TCL} + A$$

$$\text{PPI} - \text{TCL} = 2A$$

Stimulus to REF - EGM to REF interval



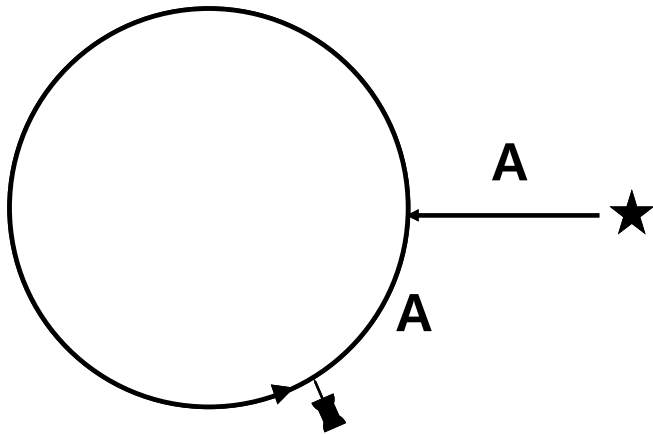
$$\text{Stim to REF} = A + B$$

$$\text{EGM to REF} = B - A$$

$$\text{Stim to REF} - \text{EGM to REF} = 2A$$

$$\text{PPI} - \text{TCL} = 2A$$

Prematurity



To increase prematurity

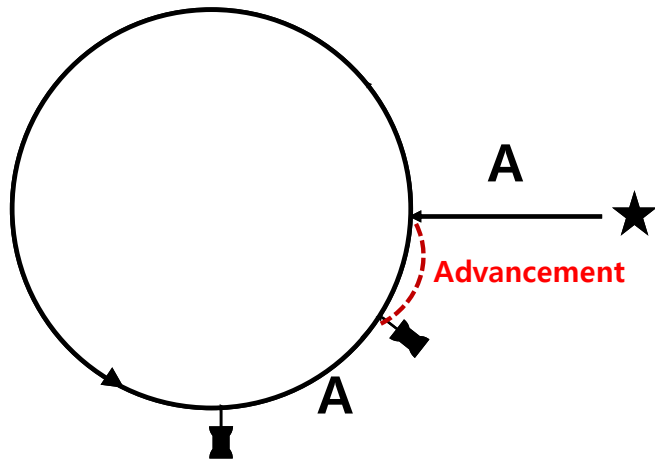
TCL - PCL. \uparrow Pacing number(N) \uparrow

$$\text{Prematurity} = (\text{TCL} - \text{PCL}) * N$$

Prematurity to reset $> 2A$

$$\text{Prematurity} = (\text{TCL} - \text{PCL}) * N > 2A = \text{PPI} - \text{TCL}$$

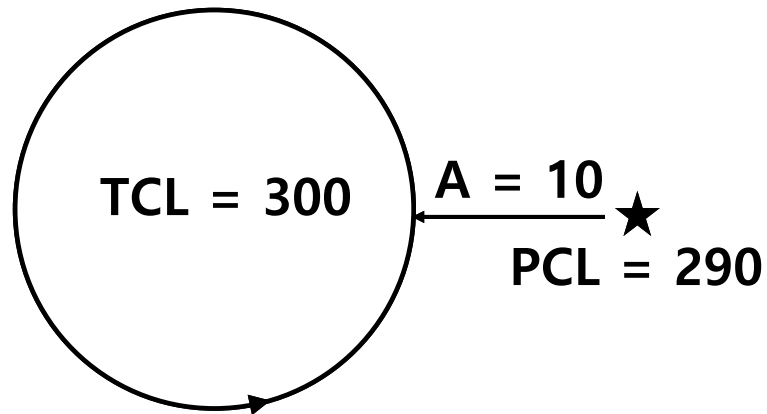
Predicted PPI



$$\text{PPI} - \text{TCL}(2A) < \text{Prematurity} = (\text{TCL} - \text{PCL}) * N$$

$$\text{PPI} - \text{TCL} = \text{Prematurity} - \text{Advancement}(B)$$

Needed Numbers to Entrain (NNE)



$$\text{PPI} - \text{TCL} = 20$$

$$\text{Prematurity} > 20$$

$$\text{PCL} = 290, \text{ NNE} = 3, \text{ advancement} = 10$$

$$(300 - 290) * N > 20$$

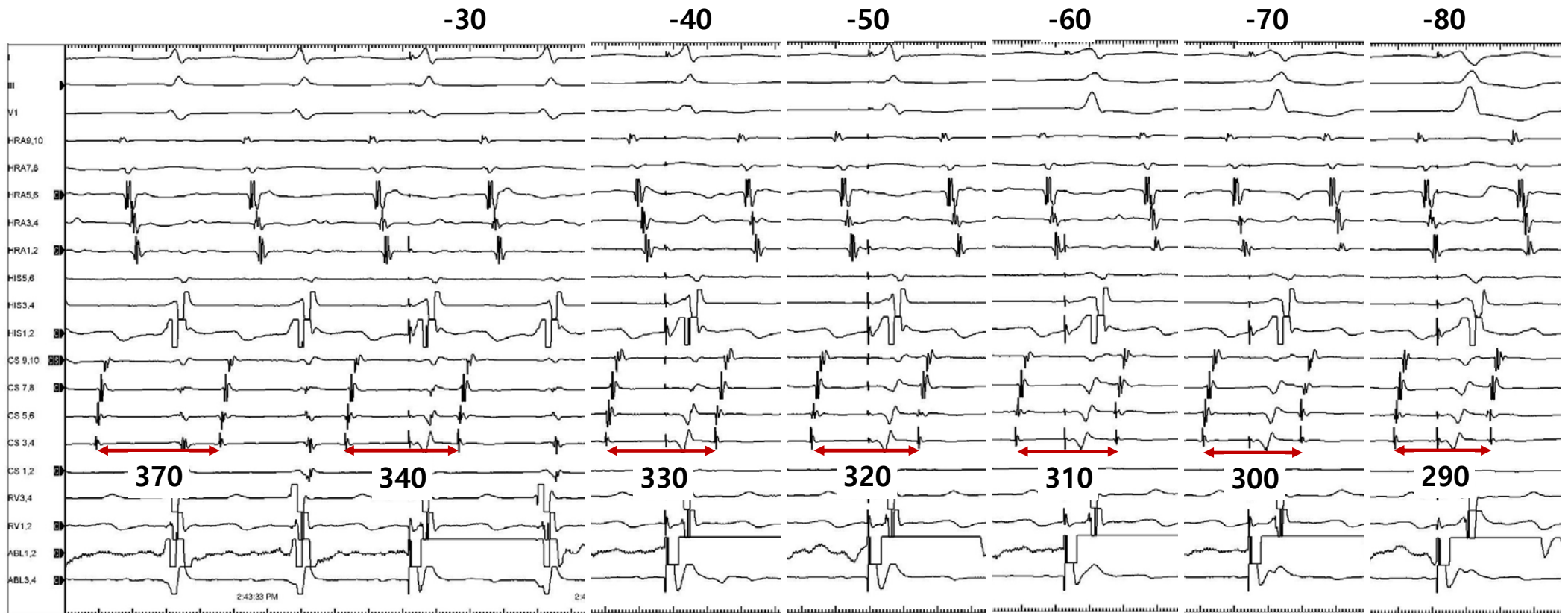
$$\text{PCL} = 280, \text{ NNE} = 2, \text{ advancement} = 20$$

$$(300 - 280) * N > 20$$

$$\text{PCL} = 270, \text{ NNE} = 1, \text{ advancement} = 10$$

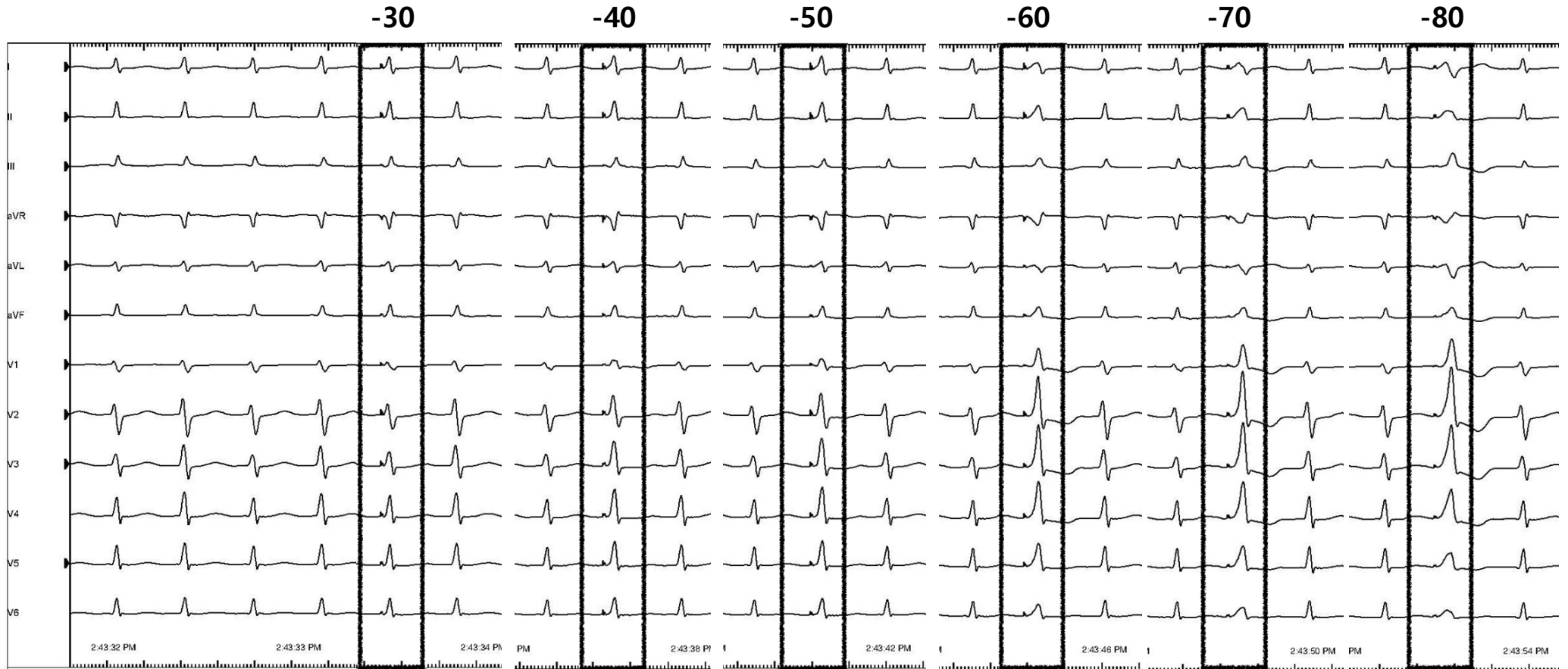
$$(300 - 270) * N > 20$$

Prematurity of single PVC in SVT

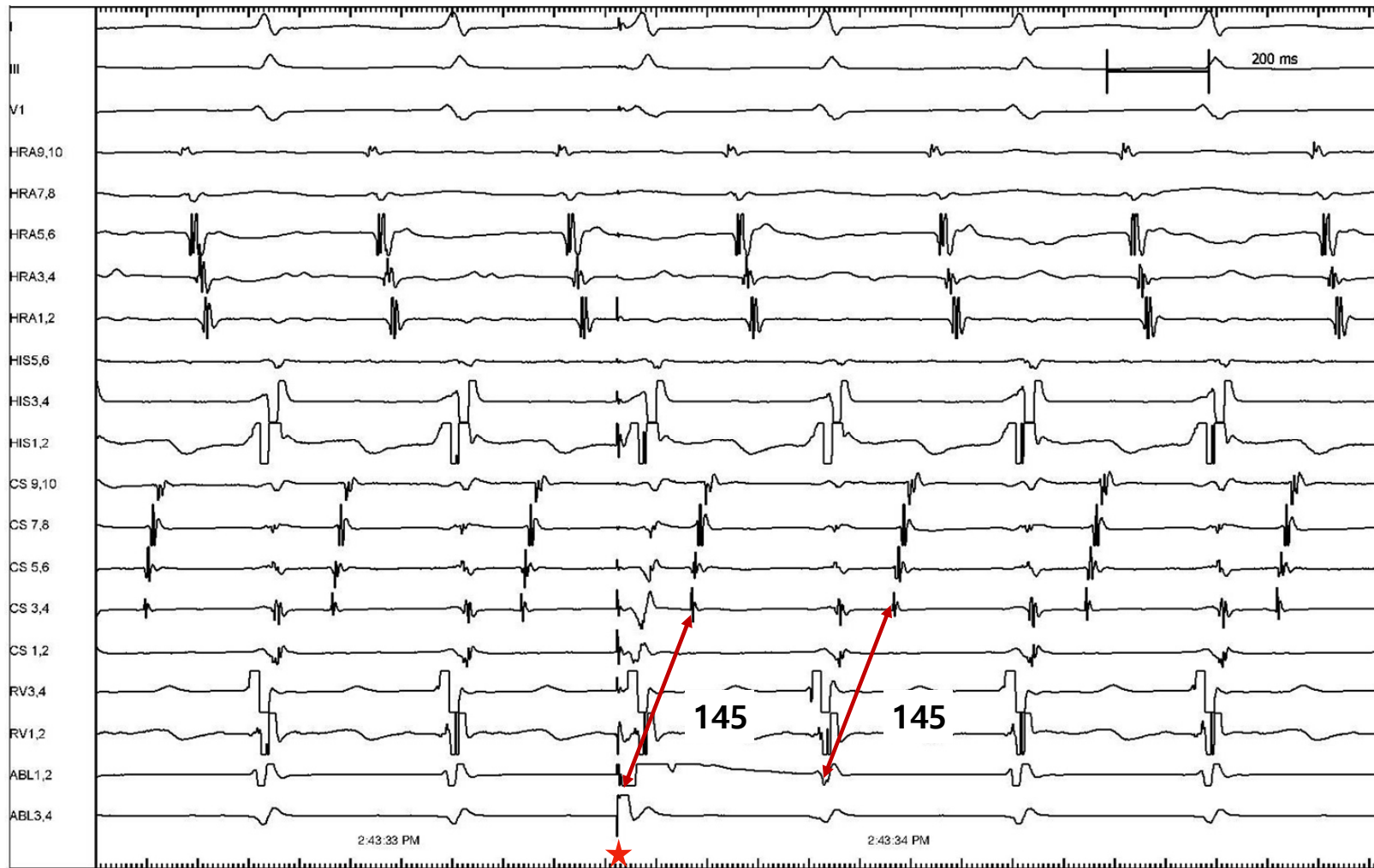


Prematurity = 30, Advancement = 30, Predicted PPI = 0, NNE = 1

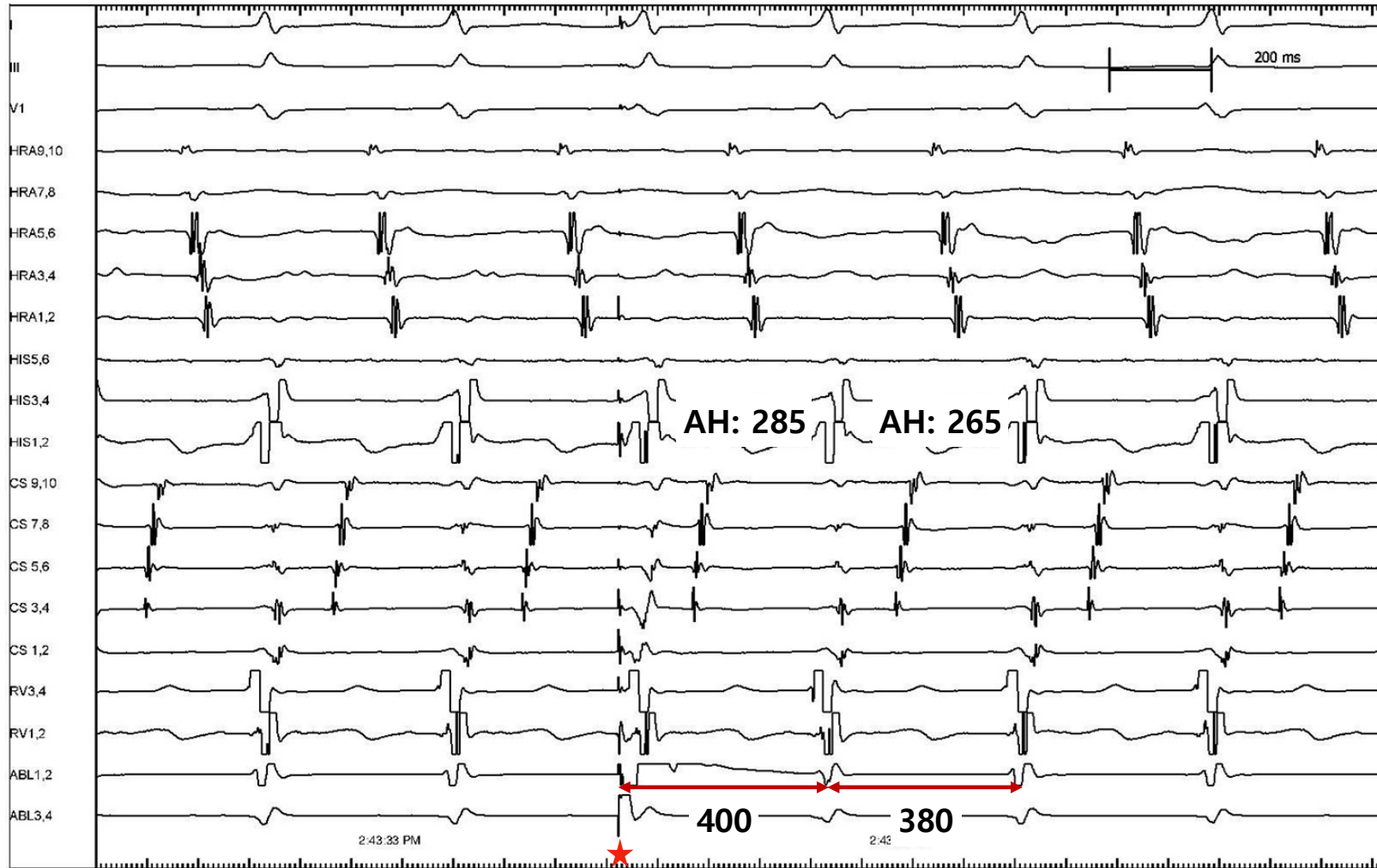
Progressive QRS fusion



Stimulus to REF - EGM to REF interval



Corrected PPI



Summary

- Achievement of entrainment establishes reentry as the mechanism.
- Concealed fusion suggests pacing site is within a protected isthmus that likely to be narrow amenable to ablation.
- Measurements related to entrainment identifies critical isthmus that contributes to reentry