Entrainment in Electrophysiologic study

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Mechanisms of tachycardia

Focal tachycardia
- Automaticity
- Triggered activity

Reentrant tachycardia
- Microreentry
- Macrotelemetry
How to distinguish tachycardia

Focal Tachycardia

- **Activation** emanates *from small area with centrifugal spread*

- **Clinical setting**
  - Multiple short burst
  - No structural heart disease or prior ablation

- **Response to overdrive pacing**
  - Automaticity: overdrive suppression
  - Triggered activity: overdrive acceleration
  - Microreentry: concealed entrainment
How to distinguish tachycardia

Reentrant Tachycardia

- Activation proceeds from the exit of *large electrical circuit*

- **Clinical setting**
  - Infrequent, sustained episodes
  - Prior ablation/surgery

- **Response to overdrive pacing**
  - Entrainment (manifest/concealed)
Why do we need 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*
  - Macroleentry: *mid-diastolic potential*
Since *ablation target* characteristics are *determined by the tachycardia mechanism*, it is *critical to make the correct diagnosis*
What is the ENTRAINMENT?

*continuous resetting*

**A** Tachycardia

**B** Resetting

- **ENTRY**
- **EXIT**
- **orth**: antidromic
- **2**: extrastimulus
Criteria for the Entrainment

1. **Fixed fusion** of the paced complexes at a constant pacing rate: *each complex an identical blend of pure pacing during sinus rhythm and tachycardia at any given PCL*

2. **Progressive fusion** or different degrees of fusion at different pacing rates: greater contribution of pacing to fused complex at faster pacing rate

3. **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
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**
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*
To declare entrainment is present, fusion must be unequivocally demonstrated (except, microreentry)

- **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 and n) activate the same chamber at the same time

**Antidromic propagation**
Wavefronts collided & perished

**Orthodromic propagation**
Penetrated the circuit & continuous reset

Almendral J, et al. PACE 2013; 36:508
PROGRESSIVE FUSION

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
Evidence of progressive fusion :: Macroleentry
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
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No progressive fusion ⊕: Focal Tachycardia
Entrainment Lingo

- Entrainment with **Manifest fusion**
- Entrainment with **Concealed fusion**
  ✓ Other entrainment criteria are met but no 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 true entrainment has not been established**
# 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 (± 20 msec)**

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

- **Concealed fusion**
- **PPI-TCL < 30 msec**
- **Stimulus-exit interval = electrogram-exit interval (± 20 msec)**
Entrainment Mapping

Entrainment with concealed fusion

- **PPI > TCL**: bystander of diastolic corridor
- **PPI ≈ TCL**: within diastolic corridor
  - S-EGM < 0.25 X diastolic interval: exit site
  - S-EGM 0.25 to 0.75 X diastolic interval: mid-corridor
  - S-EGM > 0.76 X diastolic interval: entrance site
<table>
<thead>
<tr>
<th>Site of stimulation</th>
<th>Fusion</th>
<th>S-QRS</th>
<th>PPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central isthmus</td>
<td>Concealed</td>
<td>= E-QRS in VT (30~70% of TCL)</td>
<td>= TCL</td>
</tr>
<tr>
<td>Exit site</td>
<td>Concealed</td>
<td>= E-QRS in VT</td>
<td>= TCL</td>
</tr>
<tr>
<td>Entrance site</td>
<td>Concealed</td>
<td>= E-QRS in VT</td>
<td>= TCL</td>
</tr>
<tr>
<td>Inner loop</td>
<td>Concealed</td>
<td>&lt; E-QRS in VT</td>
<td>= TCL</td>
</tr>
<tr>
<td>Bystander</td>
<td>Concealed</td>
<td>&gt; E-QRS in VT</td>
<td>&gt; TCL</td>
</tr>
<tr>
<td>Outer loop</td>
<td>Manifest</td>
<td>&lt; E-QRS in VT</td>
<td>= TCL</td>
</tr>
<tr>
<td>Away from the circuit</td>
<td>Manifest</td>
<td>varies</td>
<td>&gt; TCL</td>
</tr>
</tbody>
</table>
~ Our Story ~

M/21

C/C: LV dysfunction associated with tachycardia

Present illness

- Known CoA, S/P VSD, S/P AVR
- Underwent VSD repair at the age of 1
- Underwent AVR due to severe AR at the age of 19
- Tachycardia was detected at the regular follow up, and LV dysfunction was not improved by the medications
- He did not have many symptoms related with current status
ECG of tachycardia
ECG of tachycardia
ODP with 240 msec @ CSd
ODP with 230 msec @ CSd

1
F
V₁
HRA-p
HRA-d
His-p
His-d
CS-p
CS-d
RV
ODP with 220 msec @ CSd
ODP with 240 msec @ CSd

progressive fusion :: Macroreentry
ODP with 240 msec @ HRA
ODP with 230 msec @ HRA
ODP with 220 msec @ HRA
ODP with 240 msec @ HRA

progressive fusion

Macroreentry
ODP with 230 msec @ HRA

Stimulus artifact after onset of accelerated complex

.: Macoreenty
PVC couplets for P wave onset
Diastolic period of Tachycardia
Activation map

Voltage map
Overdrive pacing @ Corridor

271 ms  271 ms

S-IC: 160ms  E-IC: 160ms
Overdrive pacing @ CTI

264 ms  263 ms
Activation map

Voltage map
Termination @ CTI
Macoreentrant tachycardia can be terminated in any place of the circuit.

There is a big difference in pursuing the ablation target with or without understanding the exact mechanism of tachycardia.
Frequent PACs from crista after index ablation
RF application for the PAC
Initiation of AT during RF application
Atrial tachycardia

224ms  235ms  223ms  233ms
Activation Map
What’s the mechanisms of tachycardia?

Macoreentrant tachycardia?
Focal tachycardia?
Termination of Tachycardia by focal ablation
• Conduction delay can make the focal tachycardia mimic the macroreentry

• Understanding the fundamental electro-physiologic features is crucial
Summary

- The 3D high density activation mapping could not tell the exact mechanism, sometimes

- It is necessary to understand the fundamental electrophysiologic features of the tachycardia

- To know how to do overdrive pacing and its interpretation is necessary to evaluate the tachycardia mechanism and to select appropriate target site
Thank You for Your Attention!

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