Catheter Ablation of VT
Without Structural Heart Disease

성균관 의대
온 영 근
## Idiopathic Monomorphic Ventricular Tachycardia

<table>
<thead>
<tr>
<th></th>
<th>Adenosine-sensitive</th>
<th>Verapamil-sensitive</th>
<th>Propranolol-sensitive</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mech</strong> (Triggered activity)</td>
<td><strong>(Fascicular reentry)</strong></td>
<td>(Automaticity)</td>
<td></td>
</tr>
<tr>
<td>1) Exercise-induced</td>
<td>Fascicular</td>
<td>1) Exercise-induced</td>
<td></td>
</tr>
<tr>
<td>2) Repetitive monomorphic</td>
<td></td>
<td>2) Incessant</td>
<td></td>
</tr>
<tr>
<td><strong>Induction</strong> PES c/s cathecholamine</td>
<td>PES c/s cathecholamine</td>
<td>Cathecholamine</td>
<td></td>
</tr>
<tr>
<td><strong>ECG</strong> LBBB with inferior axis</td>
<td>RBBB with superior axis</td>
<td>RBBB, LBBB, Polymorphic</td>
<td></td>
</tr>
<tr>
<td>RBBB with inferior axis</td>
<td>RBBB with rt inferior axis</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Origin</strong> RVOT/LVOT</td>
<td>Lt posterior fascicle</td>
<td>Lt anterior fascicle</td>
<td>RV/LV</td>
</tr>
<tr>
<td><strong>Entrainment</strong> No</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td><strong>Adenosine</strong> Terminate</td>
<td>No effect</td>
<td>Transient suppression</td>
<td></td>
</tr>
<tr>
<td><strong>Verapamil</strong> Terminate</td>
<td>Terminate</td>
<td>No effect</td>
<td></td>
</tr>
<tr>
<td><strong>Propranolol</strong> Terminate</td>
<td>No effect</td>
<td>Terminate/Transient suppression</td>
<td></td>
</tr>
</tbody>
</table>
Ventricular Outflow Tract Tachycardia
RVOT Tachycardia

• ages of 30~50 yrs
• More frequent in women
• LBBB-like complex with tall R-waves in the inferior leads.
• 70~90% of VT patients with a structurally normal heart.
• Arrhythmia episodes
  : rare or frequent isolated PVCs, bursts of nonsustained VT, or sustained tachycardia often facilitated by catecholamines.
  : Exercise/emotion induced
• Symptoms; ranging from none to palpitations, lightheadedness, dyspnea, presyncope, or syncope.
Case 48/M recurrent palpitation
Exercise induced VT
3D mapping system
; RVOT VT RF ablation
Evaluation of RVOT Tachycardia

• Exclude structural heart disease
  - Physical examination
  - ECG
  - Echo
  - SAECG
  - MRI
  - RV angiogram and biopsy

• Rare evolution to cardiomyopathy
RVOT VT

- No evidence of underlying structural heart disease.
  - Generally benign,

It must be distinguished from other disorders associated with RV VT, such as RV dysplasia and sarcoidosis.

- Patients with symptoms not readily treated with medications are candidates for ablation.

- An ECG showing PVCs or VT can suggest the likely region of origin of the arrhythmia to assist in mapping.

- Mapping based on earliest activation
RVOT Distribution

- Majority arise 1-2 cm below the PV
- 20-30% are free wall

Joshi et al, JCE 2005;16suppl:S52
RVOT Localization

Lead I: Anterior vs Posterior

Dixit et al, JCE 2003;14:1
Joshi et al, JCE 2005;16suppl:S52
RVOT Localization

QRS: Free wall vs Septal

- QRS duration $\geq 140$ msec
- QRS notching in inferior leads
- Lead V$_3$ R/S ratio $\leq 1$

Dixit et al, JCE 2003;14:1
Joshi et al, JCE 2005;16suppl:S52
Relationship between RVOT and LVOT
Monomorphic ventricular tachycardia with LBBB morphology and an inferior axis.

DDx of RVOT and ASC origin

ABLATION OF LEFT CORONARY CUSP VT

[Diagram showing cardiovascular imaging and electrocardiographic traces with annotations LM, Abl Site, RF ON, A, V, 108 msec, 554 BPM]
• **LBBB morphologies with right inferior axis**
  
  : VT arising from the anterior septal side of the RVOT, from the right or left coronary cusp, and from the pulmonary artery.

  - **R-wave progression**: LV or the aortic cusp
  
  - **R waves in V1 and V2 and a transition by lead V3**: left-sided outflow tract VT,

  - Later transitions at V3 and V4: RVOT or the pulmonary artery
• RBBB morphology
  : VT arising in the mitral annulus adjacent to the aortic valve or from the epicardium at the outflow tract.
  - RBBB patterns with dominant R waves across the precordium : mitral annulus
Pulmonary artery VT

- Taller R in II, III, aVF
  - 1.89~1.92 mV vs 1.49~1.57 mV (PA VT vs RVOT VT)
- Larger R/S ratio in V2
  - 0.32 vs 0.17 (PA VT vs RVOT VT)
- aVL/aVR ratio of Q-wave amplitude >1 in the PA (1.11 vs 0.88 :RVOT VT)

Anatomic location of the successful ablation sites in the pulmonary artery group.

The successful ablation sites were located 1.18 ± 0.43 cm above the pulmonary valve and mostly along the septum.

## VT with LBBB morphology and inferior axis

<table>
<thead>
<tr>
<th></th>
<th>RV OT</th>
<th>PA</th>
<th>LVOT</th>
<th>ASV</th>
<th>LV epi</th>
<th>CS</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ito S</td>
<td>55(69%)</td>
<td>7(9%)</td>
<td>11(14%)</td>
<td>7(9%)</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanner</td>
<td>20(61%)</td>
<td>1(3%)</td>
<td>5(15%)</td>
<td>2(6%)</td>
<td>2(6%)</td>
<td>3(9%)</td>
<td>33</td>
</tr>
<tr>
<td>Sekiguchi Y</td>
<td>92(72%)</td>
<td>24(19%)</td>
<td>11(9%)</td>
<td>148</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Iwai S</td>
<td>100(82%)</td>
<td>22(18%)</td>
<td>12(3%)</td>
<td>122</td>
<td></td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td>267(70%)</td>
<td>25(7%)</td>
<td>58(15%)</td>
<td>12(3%)</td>
<td>383(100%)</td>
<td></td>
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</tbody>
</table>

• PES
• Burst pacing of 200~400 msec
• Isoproterenol
  Epinephrine, phenylephrine, aminophylline, Atropine,
  Ca infusion, edrophonium
• Adenosine sensitivity
• Mapping: stepwise mapping
  RVOT, PA, CS, LVOT, ASV, and epicardial
Pace Mapping

• Single point mapping to obtain $\geq 11/12$ morphologic match of the 12-lead ECG paced QRS complex to the tachycardia QRS complex.

• Successful ablation sites with identical/near identical matches.

However,

Even a perfect pace match (12/12) defines a relatively broad area of interest of $\sim 2 \text{ cm}^2$.

QRS morphology may be similar over 15 mm separation.

Sites within 5 mm may generate differences.


Clyne CA, et al. PACE 2007
Pace Mapping

<table>
<thead>
<tr>
<th></th>
<th>VT</th>
<th>24/24</th>
<th>18/24</th>
<th>12/24</th>
</tr>
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<tbody>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td></td>
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</tr>
<tr>
<td>III</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>aVR</td>
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<tr>
<td>aVL</td>
<td></td>
<td></td>
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<tr>
<td>aVF</td>
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<tr>
<td>V1</td>
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<td>V2</td>
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<td>V3</td>
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<td>V4</td>
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<tr>
<td>V5</td>
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<tr>
<td>V6</td>
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</tbody>
</table>
Activation Mapping

- Endocardial electrogram timing compared to the surface ECG.
- To detect the **earliest** endocardial activation time during tachycardia.
- 10~60 msec (mean 26~46 msec) prior to onset of the surface QRS
3D electroanatomical Mapping

• The mean area of myocardium activated within the first 10 msec was $3.0 \pm 1.6 \text{ cm}^2$ (1.3~6.4 cm$^2$).

Idiopathic Epicardial LV VT

- Perivascular sites of origin
- Catecholamine enhanced, adenosine sensitive
- 5~10% of idiopathic VT

Daniels DV, et al. Circulation. 2006;113:1659
Epicardial origin of LV VT

Multipolar catheter in Ant. Interventricular Vein

ECG of Idiopathic Epicardial LV VT

- Precordial MDI >0.55 reliably identified EPI VT.

MDI: the maximum deflection index
TMD: time to maximum deflection in precordial lead

Daniels DV, et al. Circulation. 2006;113:1659
RF ablation

- Ablation with power settings of $\leq 50$ W, a target temperature of $55\sim70^\circ$C and duration of 30~60 seconds.

- No change in the arrhythmia after 15 seconds of power delivery, it should be stopped and catheter contact and stability reassessed.

- Nonspecific response:
  
  Acceleration/gradual slowing

  Repetitive response
Complication

- Myocardial perforation with cardiac tamponade
- Heart block due to inadvertent slippage of the catheter toward the His bundle
- Injury to the LAD or left main coronary arteries
- Death, rare
Superior anteroseptum of RVOT
Pace Mapping

I

II

III

aVR

aVL

aVF

V1

V2

V3

V4

V5

V6
Activation Mapping
Normal Heart

Valves and Coronary arteries
Major coronary arteries lie in close proximity to the RVOT.
## Outcome of RFCA in Patients with Idiopathic RVOT Tachycardia

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>Acute Success</th>
<th>Mean Follow-up (mo)</th>
<th>Recurrence</th>
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<tbody>
<tr>
<td>Calkins et al. 34</td>
<td>1993</td>
<td>10</td>
<td>10/10</td>
<td>8</td>
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<tr>
<td>Coggins et al. 36</td>
<td>1994</td>
<td>20</td>
<td>17/20</td>
<td>10</td>
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<tr>
<td>Mandrola et al. 35</td>
<td>1995</td>
<td>35</td>
<td>35/35*</td>
<td>24</td>
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<tr>
<td>Movsowitz et al. 38</td>
<td>1996</td>
<td>18</td>
<td>16/18</td>
<td>12</td>
</tr>
<tr>
<td>Gumbrich et al. 33</td>
<td>1997</td>
<td>10</td>
<td>10/10</td>
<td>16</td>
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<tr>
<td>Chinushi et al. 32</td>
<td>1997</td>
<td>13</td>
<td>13/13</td>
<td>28</td>
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<tr>
<td>Rodriguez et al. 39</td>
<td>1997</td>
<td>35</td>
<td>29/35</td>
<td>30</td>
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<tr>
<td>Almendral et al. 37</td>
<td>1998</td>
<td>15</td>
<td>13/15*</td>
<td>21</td>
</tr>
<tr>
<td>Wen et al. 48</td>
<td>1998</td>
<td>44</td>
<td>39/44</td>
<td>41</td>
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<tr>
<td>Alba et al. 44</td>
<td>2001</td>
<td>50</td>
<td>47/50</td>
<td>NA</td>
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<tr>
<td>Lee et al. 63</td>
<td>2002</td>
<td>35</td>
<td>30/35</td>
<td>NA</td>
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<tr>
<td>Freidman et al. 41</td>
<td>2002</td>
<td>10</td>
<td>9/10</td>
<td>11</td>
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<td>O’Donnell et al. 22</td>
<td>2003</td>
<td>33</td>
<td>32/33</td>
<td>56</td>
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<td>Ribbing et al. 45</td>
<td>2003</td>
<td>33</td>
<td>27/33</td>
<td>54</td>
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<td>Ito et al. 53</td>
<td>2003</td>
<td>109</td>
<td>106/109</td>
<td>21</td>
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<tr>
<td>Current article</td>
<td>2005</td>
<td>72</td>
<td>71/72</td>
<td>51</td>
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<tr>
<td>Total</td>
<td>542</td>
<td>504/542(93%)</td>
<td></td>
<td>22/420 (5%)</td>
</tr>
</tbody>
</table>

Joshi et al, JCE 2005;16suppl:S52
Idiopathic Left Ventricular Tachycardia

- Fascicular Tachycardia (52%)
  - Posterior fascicular reentry
  - Anterior fascicular reentry
  - Fascicular automaticity
- ASOV Tachycardia (10%)
- LV Endocardial Tachycardia (20%)
  - Aortic root, basal septum (LVOT)
  - Mitral annular Tachycardia
- Epicardial Tachycardia (15%)
  - Anterior interventricular vein
  - Middle cardiac vein
  - Great cardiac vein
- Bundle Branch reentry (3%)
LV Fascicular Tachycardia

• ages of 15~40 yrs
• More frequent in men
• RBBB with left superior axis: Lt posterior fascicle (90~95%) inferoposterior LV septum
• RBBB with right inferior axis: Lt anterior fascicle anterosuperior LV septum
• Arrhythmia episodes
  ; sensitive to catecholamines(exercise or postexercise) or emotional stress
• ILVT reentry may be a small macroreentrant circuit.

• **Anterograde limb**: abnormal Purkinje tissue, slow decremental conduction, verapamil-sensitive diastolic potential along the midseptum

• **Retrograde limb**: Purkinje tissue from the left posterior fascicle, Purkinje potential
Late Diastolic Potential Preceding Purkinje Potential in Idiopathic LV Tachycardia

Diastolic potential (P1) and presystolic Purkinje potential (P2)

While P1 was recorded earlier from the proximal than the distal electrodes, P2 was recorded earlier from the distal than the proximal electrodes.
P1-P2 interval was gradually prolonged, and VT was terminated by block between P1 and P2. After ablation the P1 occurred after the QRS complex during sinus rhythm.

Before ablation. Diastolic potential was not observed during sinus rhythm.

After ablation, the P1 occurred after the QRS complex.

During tachycardia the LV was initially activated at the sites with DPs, then at the posterior fascicle, then at the His bundle region, and progressively at the anterior fascicle before the entire left ventricle is finally activated.
• Optimal site for catheter ablation of verapamil-sensitive ILVT

1. When **diastolic potential and presystolic Purkinje potential** are recorded from the **midseptal area during VT**, this site should be targeted.

2. If such a diastolic potential cannot be detected, the application of RF current to the **earliest ventricular activation with a fused Purkinje potential** may be carried out.

3. The appearance of **diastolic potential** after the QRS complex during **sinus rhythm** appeared to be a **useful marker for the effective RF application**.
Case

36세 남자

CC; palpitation

PI; 2005년 6월 등산 직후 palpitation 발생 30분 지속
2005년 9월 25일 등산 중 palpitation 발생 1시간 지속
2006년 6월 28일 샤워 후 palpitation 발생 1시간 지속
응급실 방문

가족력; 없음.
Inferoapical septum

RAO

LAO
Approach to ILVT

- Narrow QRS($\leq$ 140 msec), RBBB with superior axis
  - Probable fascicular tachycardia
  - Activation mapping during tachycardia
  - Earliest diastolic potentials (pacemap may be poor.)
  - Fused double potentials
    (earliest P-potential, pacemap may be good.)
Approach to ILVT

- Wider QRS (>140 msec), inferior axis
  - Atypical LB more likely on septum, aortic root or aortic SOV.
  - Monophasic R in V1 with late or no transition, more likely mitral annulus
  - Consider epicardial origin If:
    - delayed MDI(>0.55) in precordial leads
    - short presystolic endocardial activation times
    - poor endocardial pacemap matches at all sites
    - failed ablation at best endocardial target site.
Summary

• Classification of Idiopathic Monomorphic VT
  - Adenosine-sensitive (RVOT/LVOT)
  - Verapamil-sensitive (Fascicular reentry)
  - Propranolol-sensitive (Automaticity)

• Ventricular Outflow Tract Tachycardia
  - Evaluation of RVOT tachycardia
  - Localization of RVOT tachycardia by ECG
  - Anatomy of RVOT and LVOT
  - Pace mapping, Activation mapping, 3D mapping

• LV Fascicular Tachycardia
  - Purkinje Potential, Late Diastolic Potential
  - Fascicular reentry

• Approach to ILVT