Identifying the Origin of VT

ECG Correlation and Entrainment

Yan Yao, MD, PhD

Arrhythmia Center
Fuwai Heart Hospital-Cardiovascular Institute
Chinese Academy of Medical Sciences
Beijing, China
Activation of Right Ventricle (RV) during Sinus Rhythm
Activation of Left Ventricle (LV) during Sinus Rhythm
Normal QRS Vector in Three Dimensions

A

Superior

Right

Left

Inferior

Left, Inferior, and Posterior

B

Posterior

Right

Left

Anterior

Emanuel Stein
Lead Grouping According to the Region They Covered

- Inferior
- Lateral
- Septal & Posterior
- Anterior
- Lateral
- Lateral
- Lateral
- Lateral
- Lateral
The Most Common Clinical VT Types

- **Idiopathic VT:**
  - Ventricular Outflow Tract (VOT) VT:
    - RVOT VT;
    - LVOT VT;
  - Idiopathic Left VT:
    - Fascicular LVT;
    - Basal LVT;

- **Structural VT:**
  - Ischemic VT;
  - ARVC VT;
  - Bundle Branch Reentrant (BBR) VT;
  - Others (DCM, HCM, Chaga, et al.);
1, RVOT VT

- The most common VT type;
- ECG features: LBBB + Inferior QRS axis;
Anatomic Considerations

PA is superior, anterior and leftward of Aorta.
RVOT is adjacent to Aortic cusp.
Common Patterns of Outflow Tract VTs
ECG in Localizing RVOT VT

Jadonath: Am Heart J 1995;130:1107
Utility of ECG in Localizing RVOT VT

Jadonath: Am Heart J 1995;130:1107
RVOT VT ECG Patterns

**Post → Ant**

<table>
<thead>
<tr>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 2-3</th>
<th>Site 3</th>
<th>FW1</th>
<th>FW2</th>
<th>FW3</th>
</tr>
</thead>
</table>

**Septal Origin:**
- Post (1) → Ant (3)
- Lead I: positive to negative for both FW and septum

**Free Wall Origin:**
- Later precordial transition
- QRS duration ↑
- Notching in II, III, avF
- Lower amplitude in II, III, avF

*RV Coronal View*
The Value of Lead I in Localizing RVOT VT Origin
Para-Hisian RVOT VT

Yamauchi Y. J Cardiovasc Electrophysiol, 2005; 16:1041
Para-Hisian RVOT VT

Yamauchi Y. J Cardiovasc Electrophysiol, 2005; 16:1041
Multiple Origins in RVOT
Large substrate (42x38mm)
2, LVOT VT

**ECG features:**

- Inferior QRS axis;
- Broad R in lead V1 (duration > 40% of QRS, and amplitude > 30%); 
- Early transition (<V3);

VT with LCC origin
Left Coronary Cusp VT

most leftward cusp $\rightarrow$ rS in lead I;

broad R in lead $V_1$

perfect pacemap
Outflow Tract and Aortic Cusp VT

Ouyang F: JACC
2002;39:500
Spatial Relationship of LCC & RVOT Anterior Septal Origins
Anatomical Relationship Between RVOT and LVOT

Ouyang F: JACC 2002;39:500
LVOT: Mitral-Aortic Continuity

- LV epicardium
- Mitral annulus

typical RVOT locations

- RVOT inflow
- LVOT inflow
- Mitral annulus
VT/ VPC Originating from the Junction of the Left & Right Coronary Sinus of Valsalva
3. Idipathic LV Basal VT

- **ECG Patterns:**
  - The *ratio of QRS complexes in leads II / III:*
    - >1 for septal-parahisian (S-P) and lateral mitral annular (MA) sites;
    - ≤1 for aortomitral continuity (AMC), superior MA, and superolateral MA locations;
  - *Medial sites (SP/AMC) vs lateral sites (superolateral and lateral MA):*
    - *narrower* QRS complexes (134± 24 msec vs. 182± 18 msec; \( P <0.05 \))
    - *initial negative lead V1 and predominantly positive forces in lead I* (amplitude 0.59± 0.27 mV vs. 0.16± 0.34 mV; \( P <0.05 \)).

Dixit S. Heart Rhythm 2005;2:485
LV Anterior Basal VT
LVOT VT from Aorto-Mitral Continuity

- R/s in lead I
- "RBBB" in V₁
- Early precordial transition by V₃

Site of Successful Ablation
## Comparison of ECG Patterns of LVVT: Medial vs Lateral LV Sites

<table>
<thead>
<tr>
<th></th>
<th>QRS width (msec)</th>
<th>Initial negative force in lead V1</th>
<th>Early precordial transition</th>
<th>Amplitude in lead I (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial basal LV sites (S-P &amp; AMC)</td>
<td>134 ± 28 *</td>
<td>20/24 * (85%)</td>
<td>24/24 * (100%)</td>
<td>0.59 ± 0.27*</td>
</tr>
<tr>
<td>Lateral basal LV sites (Sup-Lat &amp; Lat MA)</td>
<td>182 ± 18</td>
<td>0/22</td>
<td>0/22</td>
<td>0.16 ± 34</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Septal- parahisian</th>
<th>AMC</th>
<th>Superior MA</th>
<th>Superolateral MA</th>
<th>Lateral MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead I</td>
<td>R or Rs</td>
<td>Rs or rs</td>
<td>rs or rS</td>
<td>rS or QS</td>
<td>rS or rs</td>
</tr>
<tr>
<td>Lead V1</td>
<td>QS or Qr</td>
<td>qR</td>
<td>R or Rs</td>
<td>R or Rs</td>
<td>R or Rs</td>
</tr>
<tr>
<td>Precordial transition</td>
<td>Early</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None or late</td>
</tr>
<tr>
<td>Ratio of lead II/III</td>
<td>&gt; 1</td>
<td>≤1</td>
<td>≤1</td>
<td>≤1</td>
<td>&gt; 1</td>
</tr>
</tbody>
</table>

Dixit S. Heart Rhythm 2005;2:485
### LV Basal VT ECG Patterns

<table>
<thead>
<tr>
<th>Lateral MV</th>
<th>Supero-Lat MV</th>
<th>Superior MV</th>
<th>A-M Continuity</th>
<th>Above AV</th>
<th>HIS</th>
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<tbody>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AvR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AvL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>AvF</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>V1</td>
<td></td>
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<tr>
<td>V2</td>
<td></td>
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<tr>
<td>V3</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>V4</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>V5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Medial to Lateral:**
- **R to r/s in lead I**
- **LBB to RBB in V1**
- **wider QRS**

**Epicardial:**
- **qR in lead I**
- **RBB in V1**
- **wider QRS**

**LV Posterior View**
Stepwise ECG algorithm for presuming the sites of the origin

Precordial transition in lead V1 or V2

S wave in lead V6

No

Delta-like wave (intrinsicoid deflection time ≥ 85 msec)

Yes

No

R wave polarity in Inferior leads

positive

negative

R wave in lead aVF ≥ 1.6 mV

Yes

No

Group 1 anterior

Cusps-VT

Group 2 anterolateral

Group 3 lateral

Group 4 posterior
Basal LV VT with poster-lateral MVA origin
4. Fascicular VT: posterior fascicle origin

- **ECG features**: RBBB + Left axis deviation;
Typical Ablation Target
4, Fascicular VT: anterior fascicle origin

- **ECG features:** RBBB + Right axis deviation
Left Para-Hisian VT

- **ECG features:** narrow QRS with similar morphology of sinus rhythm;
Target site: 3mm below the distal portion of His bundle
5, Ischemic VT

- Reentrant mechanism;
- The ECG only reflect the location of exit.
Summary of Specific Regions of VT Origin

Anterior Infarction
- LBBB/R-INF/any RWP pattern
- LBBB/L-INF/any RWP pattern
- RBBB/R-INF/Early Rev RWP

Inferior Infarction
- LBBB/L-SUP/increasing RWP
- LBBB/L-INF/increasing RWP
- RBBB/L-SUP/Late Rev RWP
- RBBB/R-SUP/Early Rev RWP
- RBBB/R-INF/Late Rev RWP
- RBBB/R-SUP/Late Rev RWP

Septal VT
- LBBB/R-SUP/No or late RWP

Basal VT
- LBBB/L-SUP/No or late RWP

R-WAVE PROGRESSION PATTERNS

<table>
<thead>
<tr>
<th>PATTERN</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>V5</th>
<th>V6</th>
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<tbody>
<tr>
<td>INCREASING</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>NONE/LATE</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>DOWN/UP (-) QS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>DOWN/UP (+) QS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PATTERN</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>V5</th>
<th>V6</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOMINANT</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>ABRUPT LOSS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>LATE REVERSE</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>EARLY REVERSE</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Current Mapping Strategy to Ischemic VT

Substrate Mapping
(CARTO, ESI array/NavX)

Entrainment Mapping
Entrainment Mapping

Stimulate with a CL that 20-30ms shorter than spontaneous VT at the site with MDP recorded:

1, QRS identical with VT in 12 leads;
2, Stim-QRS is about equal with MDP - QRS (±10 ms);
3, Post pacing interval (PPI) is equal with the CL of VT (±10 ms);

Pacing at the common pathway of reentrant: 1 + 2 + 3;
Pacing at out loop: fusion + 3;
Pacing outside of reentrant circuit: different morphology & PPI;
Pacing at bystander: 1 + prolonged 2 & 3;
MDP & Entrainment

1
2
3
V₁
V₆
Hisₚrox
His₃dist
RVOT
S-QRS 110 ms
CL 320 ms
RVA
Ab₂₃
Ab₁₂
S
S
S
S
PCL 280 ms
+ 200 ms +

110 ms
Ischemic VT Case

- 47 yro male with prior MI and inferior-posterior wall history.
- 2 years history of VT after CABG;
- UCG: LVED 65mm, LVEF 40%.

Sinus Rhythm

Clinical VT
The earliest potential was 14 ms earlier than ECG.
Entrainment mapping failed.
The earliest potential was 28 ms earlier than ECG;
Mapping in LV

- Concealed entrainment
- S-QRS: 24 ms
- VTCL: 356 ms
- PPI: 372 ms
6, VT with Epicardial Origin

ECG features: significantly longer pseudo-delta wave (≥ 34 ms), intrinsicoid deflection and RS complex duration compared to VT with endocardial origin.

**Identification of Epicardial Origin of VT**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudo-delta wave ≥ 34 ms</td>
<td>83%</td>
<td>95%</td>
</tr>
<tr>
<td>Intrinsicoid deflection ≥ 85 ms</td>
<td>87%</td>
<td>90%</td>
</tr>
<tr>
<td>RS complex duration ≥ 121 ms</td>
<td>76%</td>
<td>85%</td>
</tr>
</tbody>
</table>

Berruezo A. Circulation 2004;109:1842
65 yro male;
Post-MI and PTCA+CABG;
Incessant VT for 1 month;
Irrigation ablation at endocardial with 50 Watts terminated VT after 60 sec.
Epicardiac mapping of VT with isolated noncompaction of ventricular myocardium

Lim H, PACE 2006
7, ARVC VT

ECG features: LBBB + S or s wave in any of the inferior leads.
ARVC VT 40yr/M with history of presyncope
VT 1 (210bpm) terminated
VFL induced (CL 201ms)
Fast VT terminated
ARVC VTs with Multiple Exits

- 36 yro male with history of syncope.

CL 254ms
Simple Steps for VT Origin Identification

- **V1**
  - **LBBB**
  - **RBBB**
  - **Inferior Leads (II/III/avF)**
    - **S or s**
    - **R**
    - **RVOT**
    - **RVIT (ARVC ?)**
    - **LVOT or LV Basal VT**
    - **Fascicular VT**
    - **Structural VT**