# Ventricular Arrhythmias

## Mechanisms, Features, and Management

<table>
<thead>
<tr>
<th>Mahmoud Houmsse, MD, FACC</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Ohio State University Medical Center</td>
</tr>
<tr>
<td>Electrophysiology Section</td>
</tr>
<tr>
<td>Cardiovascular Medicine</td>
</tr>
</tbody>
</table>

---

## Ventricular Tachycardia (VT)

Classification by the heart structure

- Scar based VT
- Normal Heart Structure VT
Scar Related VT’s

- Healed MI
- Idiopathic dilated cardiomyopathy
- RV Dysplasia
- Hypertrophic cardiomyopathy
- Sarcoid
- Chagas disease
- Repaired Tetralogy of Fallot

VT Circuit – Ischemic VT

- Outer loop
- Blind alley
- Exit
- Isthmus

Average Circuit size 3 to 4 cm
### Idiopathic Ventricular Tachycardia

#### Normal Structure Heart

- **Outflow Tract**
  - RVOT 70%
  - LVOT
  - Ao Cusp

- **Fascicular**
  - LPF
  - LAF
  - Septal

- **Annular**
  - MA
  - TA

- **Adrenergic**

---

### Mechanism of Idiopathic VT

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reentrant</strong></td>
<td>Verapamil sensitive&lt;br&gt;Reproduced by program stimulation&lt;br&gt;Can be Cathecholamine-Sensitive</td>
</tr>
<tr>
<td><strong>Automaticity</strong></td>
<td>Adrenergically Mediated&lt;br&gt;Usually Spontaneous&lt;br&gt;Not induced by program stimulation&lt;br&gt;Overdrive Suppression</td>
</tr>
<tr>
<td><strong>Triggered Activity</strong></td>
<td>Mediated by stimulation of c-AMP&lt;br&gt;Adenosine-Sensitive&lt;br&gt;Delayed Afterdepolarizations (DADs)&lt;br&gt;Catecholamine Sensitive&lt;br&gt;Induced with Overdrive Pacing</td>
</tr>
</tbody>
</table>
### Classification by VT Morphology

- **Monomorphic Vs. Polymorphic VT**
- **Torsades de pointes:** polymorphic VT + long QT interval
- **Bidirectional VT:** (digitalis toxicity)
- **Ventricular flutter is regular, rapid =300 bpm**
- **Ventricular fibrillation (VF):** rapid, >300 bpm

### Classification by VT Duration

**Sustained VT:**
- >30 seconds
- < 30 seconds need termination d/t hemodynamic instability

**Nonsustained VT**
- > or = 3 beats VT (>100 beats/min)
- <30 seconds

**Incessant VT:**
- Sustained VT, recurrent post termination by cardioversion
- Repeated bursts runs of VT
Sustained Monomorphic VT

Non-Sustained Monomorphic VT
Non-Sustained Polymorphic VT

Sustained Polymorphic VT
Exercise induced in patient with no structural heart disease
Torsades de Pointes
Spontaneous conversion to NSR (continuous lead II monitor strip)

Ventricular Flutter
Spontaneous conversion of NSR (12-lead ECG)
VF with Defibrillation (12-lead ECG)

Wide QRS Irregular Tachycardia:
Atrial Fibrillation with antidromic conduction in patient with accessory pathway – Not VT
Classification by Clinical Presentation

**Hemodynamically stable**
- ♥ Asymptomatic
- ♥ Minimal symptoms, e.g., palpitations

**Hemodynamically unstable**
- ♥ Presyncope
- ♥ Syncope
- ♥ Sudden cardiac death
- ♥ Sudden cardiac arrest

Epidemiology of VA & SCD

**Incidence of Sudden Cardiac Death**

![Incidence and Events Graphs]

Circulation 1992;85:12-10.
Mechanisms & Substrates of SCD

Mechanisms of Sudden Cardiac Death in 157 Ambulatory Patients

• Ventricular fibrillation - 62.4%
• Bradyarrhythmias (including advanced AV block and asystole) - 16.5%
• Torsades de pointes - 12.7%
• Primary VT - 8.3%


Clinical Presentations of VA & SCD

• **Asymptomatic** individuals +/- abnormal ECG
• Persons with symptoms potentially **attributable to VA**
  - Palpitations
  - Dyspnea
  - Chest pain
  - Syncope and presyncope
• VT that is hemodynamically **stable**
• VT that is **not hemodynamically** stable
• **Cardiac arrest**
  - Asystolic (sinus arrest, atrioventricular block)
  - VT
  - Ventricular fibrillation (VF)
  - Pulseless electrical activity
### General Evaluation for Documented or Suspected VA

**Resting Electrocardiogram**

Resting 12-lead ECG is indicated in all patients who are evaluated for ventricular arrhythmias.

### WPW ECG pattern

**notice short PR interval and delta wave**

![Electrocardiogram showing WPW pattern](image)
Arrhythmogenic RV Cardiomyopathy
(RV conduction delay, inverted T-waves V1-V5)

12-lead ECG showing Epsilon wave

Arrhythmogenic RV Cardiomyopathy
12-lead ECG showing Epsilon wave
Long QT Syndrome in a 16-year-old girl
QT=520 ms; Atrial Tachycardia with 2:1 AV conduction

Brugada Syndrome
(Typical ST-T abnormality V1-V2)
### General Evaluation for Documented or Suspected VA

#### Exercise Testing
Intermediate or greater probability of having CAD by symptoms to provoke ischemic changes or VA

Known or Suspected exercise-induced VA, including catecholaminergic VT, to *provoke* the arrhythmia, achieve a *diagnosis*, and determine the *patient’s response* to tachycardia.

Response to medical or ablation therapy in patients with known exercise-induced ventricular arrhythmias

---

#### General Evaluation for Documented or Suspected VA

#### Ambulatory Electrocardiography

QT- interval changes, T-wave alternans (TWA), or ST changes to evaluate risk, or to judge therapy.

Event monitors are indicated when symptoms sporadic

Implantable recorders are useful in patients sporadic syncope when a symptom-rhythm correlation cannot be established.
**General Evaluation for Documented or Suspected VA**

### Electrocardiographic Techniques

- T-wave alternans: risk stratification for VA or who are at risk for developing life-threatening ventricular arrhythmias. (*-ve predictive value*)

- Signal-averaged ECG (SAECG)
- Heart rate variability (HRV)
- Baroreceptor reflex sensitivity
- Heart rate turbulence

### Echocardiography

- Suspected of having structural heart disease.

- Subset of patients at high risk for VA or SCD:
  - Dilated, hypertrophic, or RV cardiomyopathies,
  - AMI survivors.
  - Relatives of patients with inherited disorders associated with SCD (channelopathy)
## General Evaluation for Documented or Suspected VA

### Stress testing and Imaging (nuclear or echo)
- Detect silent ischemia in patients with VA
- ECG assessment is less reliable because of:
  1. Digoxin use
  2. LVH
  3. > 1-mm ST-segment depression at rest
  4. Wolf-Parkinson-White (WPW) syndrome
  5. Left Bundle Branch Block (LBBB).
  6. Paced ventricular rhythm.

---

## General Evaluation for Documented or Suspected VA

### Left Ventricular Function and Imaging

MRI, cardiac computed tomography (CT), or radionuclide angiography (muga scan) can be useful VA when *echocardiography does not provide* accurate assessment of left ventricular (LV) & RV function.

*Coronary angiography* can be useful to assess for any significant *obstructive CAD* in life-threatening VA or in survivors of SCD.
### General Evaluation for Documented or Suspected VA

#### Conditions Associated With VA That Can Be Diagnosed With Echocardiography

<table>
<thead>
<tr>
<th>Disease Entity</th>
<th>Diagnostic Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dilated cardiomyopathy</td>
<td>High</td>
</tr>
<tr>
<td>Ischemic cardiomyopathy</td>
<td>High</td>
</tr>
<tr>
<td>Hypertension with moderate to severe LVH</td>
<td>High</td>
</tr>
<tr>
<td>Valvular heart disease</td>
<td>High</td>
</tr>
<tr>
<td>Arrhythmogenic right ventricular cardiomyopathy (ARVC)</td>
<td>Moderate</td>
</tr>
<tr>
<td>Brugada syndrome</td>
<td>Poor</td>
</tr>
</tbody>
</table>

#### Electrophysiological Testing in CAD

- Remote MI with symptoms suggestive of ventricular tachyarrhythmias, including palpitations, presyncope, and syncope.
- Assess the efficacy of VT ablation.
- Diagnostic evaluation of wide-QRS-complex tachycardias.
- Risk stratification in remote MI, NSTV, @ LVEF ≤ 40%.
### General Evaluation for Documented or Suspected VA

#### Electrophysiological Testing in Patients With Syncope

1. Impaired LV function or structural heart disease.

2. Bradyarrhythmias or tachyarrhythmias are suspected and in whom noninvasive diagnostic studies are not conclusive.

### Management of VA
Sustained Monomorphic VT (SMVT)

- **Wide-QRS tachycardia** should be **presumed to be VT** if the Dx is unclear.

- **Cardioversion** is recommended in suspected SMVT with **hemodynamic compromise**

- Intravenous *procainamide* is reasonable for **stable** SMVT

**Sustained Monomorphic VT (SMVT)**

- Intravenous *amiodarone* is reasonable in SMVT:  
  1. Hemodynamically unstable  
  2. Refractory to cardioversion  
  3. Recurrent despite antiarrhythmic medications

- **Transvenous catheter pace** termination can be useful in:  
  1. Refractory to cardioversion.  
  2. Recurrent despite antiarrhythmic medication.
**Acute Management of Specific Arrhythmias**

**Sustained Monomorphic VT (SMVT)**

- *Intravenous lidocaine* might be reasonable SMVT in acute myocardial ischemia or infarction.

- *Verapamil and diltiazem* should **not** be used in patients to terminate wide-QRS- complex tachycardia of unknown origin, especially history of myocardial dysfunction.

**Acute Management of Specific Arrhythmias**

**Polymorphic VT (PMVT)**

- *Direct-current cardioversion* is recommended PMVT with hemodynamic compromise.

- *Intravenous beta blockers* are useful in recurrent PMVT, especially if ischemia is suspected.

- Intravenous amiodarone can be used in **no** congenital or acquired LQTS exist.
### Acute Management of Specific Arrhythmias

**Torsades de Pointes (Tdp)**

- *Withdrawal* of any offending drugs
- *Correction* of electrolyte abnormalities
- Acute and long-term pacing
  - Heart block
  - Symptomatic bradycardia

---

**Intravenous Magnesium sulfate** is effective in *LQTS* and few episodes of Tdp.

- *Acute and long-term pacing* is reasonable in *recurrent pause-dependent Tdp.*

- *Isoproterenol* is reasonable as temporary treatment in *recurrent pause-dependent do not* have congenital LQTS.
### Therapies for VA

- **Beta Blockers:** Effectively suppress PVC & arrhythmias; reduce incidence of SCD

- **Amiodarone:** No definite survival benefit; Has complex drug interactions and many adverse side effects (pulmonary, hepatic, thyroid, cutaneous)

- **Sotalol:** pro-arrhythmic > amiodarone, no survival benefit

- **Antiarrhythmic drugs (except for BB) should not be used as primary therapy of VA and the prevention of SCD**

---

### Therapies for VA

- **Electrolytes:** esp in setting of hypomagnesemia and hypokalemia

- **ACE inhibitors, ARB and aldosterone blockers** can improve the myocardial substrate through reverse remodeling

- **Antithrombotic and antiplatelet agents:** reducing coronary thrombosis

- **Statins:** have been shown to reduce life-threatening VA in high-risk patients with electrical instability

- **n-3 Fatty acids:** conflicting data exist for the prevention of SCD
Therapies for VA
ICDs: Results from Primary and Secondary Prevention Trials

<table>
<thead>
<tr>
<th>Trial Name, Pub Year</th>
<th>N</th>
<th>Hazard ratio</th>
<th>LVEF, other features</th>
</tr>
</thead>
<tbody>
<tr>
<td>MADIT-I 1996</td>
<td>1016</td>
<td>0.46</td>
<td>0.35 or less, NSVT, EP positive</td>
</tr>
<tr>
<td>AVID 1997</td>
<td>191</td>
<td>0.83</td>
<td>Aborted cardiac arrest</td>
</tr>
<tr>
<td>CABG-Patch 1997</td>
<td>650</td>
<td>1.07</td>
<td>0.35 or less, abnormal SAECG and scheduled for CABG</td>
</tr>
<tr>
<td>CASH* 2000</td>
<td>191</td>
<td>0.83</td>
<td>Aborted cardiac arrest</td>
</tr>
<tr>
<td>CID 2009</td>
<td>650</td>
<td>0.62</td>
<td>Aborted cardiac arrest or syncope</td>
</tr>
<tr>
<td>MADIT-II 2002</td>
<td>1232</td>
<td>0.69</td>
<td>0.30 or less, prior MI</td>
</tr>
<tr>
<td>DEFINITE 2004</td>
<td>458</td>
<td>0.65</td>
<td>0.35 or less, NICM and PVCs or NSVT</td>
</tr>
<tr>
<td>DINAMIT 2004</td>
<td>674</td>
<td>0.65</td>
<td>0.35 or less, MI within 6 to 40 days and impaired cardiac autonomic function</td>
</tr>
<tr>
<td>SCD-HeFT 2005</td>
<td>1676</td>
<td>0.77</td>
<td>0.35 or less, LVD due to prior MI and NICM</td>
</tr>
</tbody>
</table>

Therapies for VA
Primary Prevention of SCD
LV dysfunction due to MI, LVEF ≤ 30%, NYHA class I

LV dysfunction due to MI, LVEF ≤ 31-35%, NYHA class I

LV dysfunction due to MI, LVEF ≤ 30%, NYHA class II, III

LV dysfunction due to MI, LVEF 30-35%, NYHA class II, III

LV dysfunction due to MI, LVEF 30-40%, NSVT, positive EP study
### Therapies for VA

#### Primary Prevention of SCD

<table>
<thead>
<tr>
<th>Nonischemic cardiomyopathy, LVEF ≤ 30%, NYHA class II, III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonischemic cardiomyopathy, LVEF 30-35%, NYHA class II, III</td>
</tr>
</tbody>
</table>

#### Ablation

- Low risk for SCD and have sustained predominantly monomorphic VT (drug resistant, drug intolerant, do not wish long-term drug therapy)

- Multiple appropriate ICD shocks due to VA.  
  *(not manageable by reprogramming or drug change, and do not wish long-term drug therapy)*

- WPW syndrome resuscitated from sudden cardiac arrest due to AF and rapid conduction over the accessory pathway causing VF.
## Therapies for VA

<table>
<thead>
<tr>
<th>Ablation</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ Low risk for SCD &amp; symptomatic non-sustained monomorphic VT (drug resistant, drug intolerant, do not wish long-term drug therapy)</td>
</tr>
<tr>
<td>➢ Low risk for SCD and frequent symptomatic monomorphic PVCs (drug resistant, drug intolerant, do not wish long-term drug therapy)</td>
</tr>
<tr>
<td>➢ Asymptomatic frequent PVCs may be considered to avoid or treat tachycardia-induced cardiomyopathy (TIC)</td>
</tr>
<tr>
<td>➢ <em>Bundle-branch reentrant VT.</em></td>
</tr>
</tbody>
</table>

## VA Associated With Cariomyopathies
### Risk Factors for Sudden Cardiac Death in Hypertrophic Cardiomyopathy

**Major Risk Factors**
- Cardiac arrest (VF)
- Spontaneous sustained VT
- Family history of premature sudden death
- Unexplained syncope
- LV thickness $\geq 30$ mm
- Abnormal exercise BP
- Non-sustained spontaneous VT


### Arrhythmogenic Right Ventricular Cardiomyopathy (ARVC)

- ICD implantation is recommended for the prevention of SCD in ARVC with documented sustained VT or VF

- ICD implantation can be effective for the prevention of SCD in ARVC
  1. Extensive disease
  2. 1 or more affected family member with SCD
  3. Undiagnosed syncope
### Arrhythmogenic Right Ventricular Cardiomyopathy (ARVC)

- Amiodarone or sotalol *can be effective* in ARVC when ICD implantation is not feasible.

- *Ablation* can be useful as *adjunctive* therapy in ARVC with recurrent VT

### Genetic Arrhythmia Syndromes
Long QT Syndrome

- *Lifestyle modification* is recommended for LQTS patients
- Beta blockers are recommended in the presence of prolonged QT
- Implantation of an ICD + beta blockers is recommended for LQTS patients with previous cardiac arrest

Brugada Syndrome

- An ICD is indicated for Brugada syndrome patients with previous cardiac arrest
- An ICD is reasonable for Brugada syndrome patients with spontaneous ST-segment elevation in V₁, V₂, or V₃ who have had syncope
# Drug Interactions Causing Arrhythmias

<table>
<thead>
<tr>
<th>Drug</th>
<th>Interacting Drug</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digoxin</td>
<td>Some antibiotics</td>
<td>Eliminating gut flora that metabolize digoxin</td>
</tr>
<tr>
<td>Digoxin</td>
<td>✓ Amiodarone ✓ Quinidine ✓ Verapamil</td>
<td>Increased digoxin bioavailability, reduced biliary and renal excretion due to P-glycoprotein inhibition</td>
</tr>
<tr>
<td></td>
<td>✓ Cyclosporine ✓ Itraconazole ✓ Erythromycin</td>
<td>Digoxin toxicity</td>
</tr>
<tr>
<td>Quinidine</td>
<td>Ketoconazole</td>
<td>Increased drug levels</td>
</tr>
<tr>
<td>Cisapride</td>
<td>Itraconazole</td>
<td></td>
</tr>
<tr>
<td>Terfenadine</td>
<td>Erythromycin*</td>
<td></td>
</tr>
<tr>
<td>astemizole</td>
<td>Clarithromycin Some calcium channel blockers* Some HIV protease inhibitors (especially ritonavir)</td>
<td></td>
</tr>
</tbody>
</table>

## Drug Interactions Causing Arrhythmias

<table>
<thead>
<tr>
<th>Drug</th>
<th>Interacting Drug</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta blockers</td>
<td>Propafenone</td>
<td>Increased beta blockade</td>
</tr>
<tr>
<td></td>
<td>Quinidine (even ultra-low dose)</td>
<td>Increased beta blockade</td>
</tr>
<tr>
<td></td>
<td>Fluoxetine</td>
<td></td>
</tr>
<tr>
<td>Flecaainide</td>
<td>Some tricyclic antidepressants</td>
<td>Increased adverse effects</td>
</tr>
<tr>
<td>Dofetilde</td>
<td><em>Verapamil (not Diltiazem)</em></td>
<td>Increased plasma dofetilde concentration</td>
</tr>
<tr>
<td></td>
<td><em>Cimetidine</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Trimethoprim</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Ketoconazole</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Megestrol</em></td>
<td></td>
</tr>
</tbody>
</table>


## Drug Interactions Causing Arrhythmias

<table>
<thead>
<tr>
<th>Drug</th>
<th>Interacting Drug</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>QT-prolonging</td>
<td>Diuretics</td>
<td>Increased T de P risk due to diuretic-induced hypokalemia</td>
</tr>
<tr>
<td>antiarrhythmics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beta blockers</td>
<td>Amiodarone, clonidine, digoxin, diltiazem, verapamil</td>
<td>Bradycardia when used in combination</td>
</tr>
<tr>
<td>Digoxin</td>
<td>Amiodarone, beta blockers, clonidine, diltiazem, verapamil</td>
<td></td>
</tr>
<tr>
<td>Verapamil</td>
<td>Amiodarone, beta blockers, clonidine, digoxin, diltiazem</td>
<td></td>
</tr>
<tr>
<td>Diltiazem</td>
<td>Amiodarone, beta blockers, clonidine, digoxin, verapamil</td>
<td></td>
</tr>
<tr>
<td>Sildenafil</td>
<td>Nitrates</td>
<td>Increased and persistent vasodilation; risk of myocardial ischemia</td>
</tr>
<tr>
<td>Clonidine</td>
<td>Amiodarone, beta blockers, digoxin, diltiazem, verapamil</td>
<td></td>
</tr>
<tr>
<td>Amiodarone</td>
<td>Beta blockers, clonidine, digoxin, diltiazem, verapamil</td>
<td></td>
</tr>
</tbody>
</table>
Examples of Drugs Causing Torsades de Pointes

<table>
<thead>
<tr>
<th>Frequent (greater than 1%)*</th>
<th>Less Frequent</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Disopyramide</td>
<td>• Amiodarone</td>
</tr>
<tr>
<td>• Dofetilide</td>
<td>• Arsenic trioxide</td>
</tr>
<tr>
<td>• Ibutilide</td>
<td>• Bepridil</td>
</tr>
<tr>
<td>• Procainamide</td>
<td>• Cisapride</td>
</tr>
<tr>
<td>• Quinidine</td>
<td>• Anti-infectives: clarithromycin, erythromycin, halofantrine; pentamidine, sparfloxacin</td>
</tr>
<tr>
<td>• Sotalol</td>
<td>• Antiemetics: domperidone, droperidol</td>
</tr>
<tr>
<td>• Ajmaline</td>
<td>• Antipsychotics: chlorpromazine, haloperidol, mesoridazine, thioridazine, pimozide</td>
</tr>
</tbody>
</table>

* (e.g., hospitalization for monitoring recommended during drug initiation in some circumstances)


Risk Factors for Drug-Induced Torsades de Pointes

- Female gender
- Hypokalemia
- Bradycardia
- Recent conversion from atrial fibrillation
- Congestive heart failure
- Digitalis therapy
- Severe hypomagnesemia
- Congenital long QT syndrome
- Baseline QT prolongation