Objectives

Upon completion of this preceptorship, the participant should be able to:

- Identify three patient symptoms related to a decrease in cardiac output.
- Name and explain the three American College of Cardiology/American Heart Association (ACC/AHA) classes relating to pacing implant guidelines.
- List three pacing indication areas as defined by the ACC/AHA pacing guidelines.
Causes of Rhythm and Conduction Defects

- Coronary artery disease
- Calcified valve disease
- Endocarditis or Myocarditis
- Heart surgery
- Congenital
General Disorders That May Require Pacing

Rhythm
- Bradycardia
- Brady/tachy syndrome
- Tachycardia

Conduction
- Complete AV block
- Second degree AV block
- Intraventricular conduction defects

Others
- Neurocardiogenic syndromes
Pacing Therapy Objectives

Provide appropriate heart rate
Preserve AV function

Prolong life and prevent symptoms with minimal risks
Maximize hemodynamics
ACC/AHA Guidelines for Implantation of Pacemakers & Antiarrhythmia Devices

• **Class I:**
  Conditions for which there is evidence and/or general agreement that a given procedure or treatment is beneficial, useful, and effective.

• **Class II:**
  Conditions for which there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a procedure or treatment.
  - **Class II a:** Weight of evidence/opinion is in favor of usefulness/efficacy.
  - **Class II b:** Usefulness/efficacy is less well established by evidence/opinion

• **Class III:**
  Conditions for which there is evidence and/or general agreement that a procedure/treatment is not useful/effective and in some cases may be harmful.
Pacing Indications

A. Pacing for Acquired Atrioventricular Block in Adults
B. Pacing for Chronic Bifascicular and Trifascicular Block
C. Pacing for Atrioventricular Block Associated with Acute Myocardial Infarction
D. Pacing in Sinus Node Dysfunction
E. Prevention and Termination of Tachyarrhythmias by Pacing
F. Pacing in Hypersensitive Carotid Sinus and Neurocardiogenic Syncope
G. Pacing in Children, Adolescents, and Patients with Congenital Heart Disease
H. Pacing in Specific Conditions
Acquired Atrioventricular Block in Adults

Class I

1. Third-degree and advanced 2\textsuperscript{nd} degree AV block at any anatomic level, associated with any one of the following conditions:

   a) Bradycardia with symptoms (including heart failure) presumed to be due to AV block

   b) Arrhythmias and other medical conditions that require drugs that result in symptomatic bradycardia

   c) Documented periods of asystole $\geq 3.0$ seconds or any escape rate $< 40$ beats per minute (bpm) in awake, symptom-free patients

   d) After catheter ablation of the AV junction. There are no trials to assess outcome without pacing, and pacing is virtually always planned in this situation unless the operative procedure is AV junction modification
Class I (continued)

e) Postoperative AV block that is not expected to resolve after cardiac surgery

f) Neuromuscular diseases with AV block such as myotonic muscular dystrophy, Kearns-Sayre Syndrome, Erb’s dystrophy (limb-girdle), and peroneal muscular atrophy, with or without symptoms, because there may be unpredictable progression of AV conduction disease

2. Second-degree AV block regardless of type or site of block, with associated symptomatic bradycardia
Acquired Atrioventricular Block in Adults

Class IIa

1. Asymptomatic third-degree AV block at any anatomic site with average awake ventricular rates of 40 bpm or faster, especially if cardiomegaly or LV dysfunction is present

2. Asymptomatic type II second-degree AV block with a narrow QRS when type II 2nd degree AV block occurs with a wide QRS, pacing becomes a Class I recommendation

3. Asymptomatic type I second degree block at intra- or infra-His levels found at EP Study performed for other indications

4. First or second degree AV block with symptoms similar to those of pacemaker syndrome
Class IIb

1. Marked first-degree AV block (>0.30 second) in patients with LV dysfunction and symptoms of CHF in whom a shorter AV interval results in hemodynamic improvement, presumably by decreasing left atrial filling pressure.

2. Neuromuscular diseases such as myotonic muscular dystrophy, Kearns-Sayre Syndrome, Erb’s dystrophy (limb girdle) and peroneal muscular atrophy with any degree of AV block (including first-degree AV block), with or without symptoms, because there may be unpredictable progression of AV conduction disease.
Acquired Atrioventricular Block in Adults

Class III

1. Asymptomatic first-degree AV block

2. Asymptomatic type I second-degree AV block at the supra-His (AV node) level or not known to be intra- or infra-Hisian

3. AV block expected to resolve and unlikely to recur (eg, drug toxicity, Lyme disease or during hypoxia in sleep apnea syndrome in absence of symptoms)
Chronic Bifascicular and Trifascicular Block

**Class I**

1. Intermittent third-degree AV block
2. Type II second-degree AV block
3. Alternating bundle-branch block
Chronic Bifascicular and Trifascicular Block

Class Ila

1. Syncope not demonstrated to be due to AV block when other likely causes have been excluded, specifically ventricular tachycardia (VT)

2. Incidental finding at electrophysiological study of markedly prolonged HV interval (≥100 milliseconds) in asymptomatic patients

3. Incidental finding at electrophysiological study of pacing-induced infra-His block that is not physiological
Chronic Bifascicular and Trifascicular Block

Class IIb
Neuromuscular diseases such as myotonic muscular dystrophy, Kearns-Sayre syndrome, Erb’s dystrophy (limb-girdle), and peroneal muscular atrophy with any degree of fascicular block, with or without symptoms, because there may be unpredictable progression of AV conduction disease

Class III
1. Fascicular block without AV block or symptoms
2. Fascicular block with 1st degree AV block w/o symptoms
A/V Block Associated with Acute Myocardial Infarction

Class I

1. Persistent second-degree AV block in the His-Purkinje system with bilateral bundle branch block or third-degree AV block within or below the His-Purkinje system after AMI

2. Transient advanced (second- or third-degree) intranodal AV block and associated bundle branch block. If the site of block is uncertain, an electrophysiological study may be necessary

3. Persistent and symptomatic second- or third-degree AV block
A/V Block Associated with Acute Myocardial Infarction

Class II a
None

Class II b
Persistent second-degree AV block at the AV node level
A/V Block Associated with Acute Myocardial Infarction

Class III

1. Transient AV block in the absence of intraventricular conduction defects
2. Transient AV block in the presence of isolated left anterior fascicular block
3. Acquired left anterior fascicular block in the absence of AV block
4. Persistent first-degree AV block in the presence of bundle branch block that is old or age indeterminate
Sinus Node Dysfunction

Class I

1. Sinus node dysfunction with documented symptomatic bradycardia, including frequent sinus pauses that produce symptoms. In some patients, bradycardia is iatrogenic and will occur as a consequence of essential long-term drug therapy of a type and dose for which there are no acceptable alternatives.

2. Symptomatic chronotropic incompetence
Sinus Node Dysfunction

Class IIa

1. Sinus node dysfunction occurring spontaneously or as a result of drug therapy, with heart rate < 40 bpm when a clear association between significant symptoms consistent with bradycardia and it has not been documented.

2. Syncope of unexplained origin when major abnormalities of sinus node function are discovered or provoked in EP studies.

Class II b

In minimally symptomatic patients, chronic heart rate < 40 bpm while awake.
Sinus Node Dysfunction

Class III

1. Sinus node dysfunction in asymptomatic patients, including those where substantial sinus bradycardia (heart rate < 40 bpm) is a consequence of long-term drug treatment.

2. Sinus node dysfunction in patients with symptoms suggestive of bradycardia that are clearly documented as not associated with a slow heart rate.

3. Sinus node dysfunction with symptomatic bradycardia due to nonessential drug therapy.
Devices that Automatically Detect and Pace to Terminate Tachycardias

**Class I**

None

**Class IIa**

Symptomatic recurrent supraventricular tachycardia that is reproducibly terminated by pacing after drugs and catheter ablation fail to control the arrhythmia or produce intolerable side effects

**Class IIb**

Recurrent supraventricular tachycardia or atrial flutter that is reproducibly terminated by pacing as an alternative to drug therapy or ablation
Devices that Automatically Detect and Pace to Terminate Tachycardias

Class III

1. Tachycardias frequently accelerated or converted to fibrillation by pacing

2. The presence of accessory pathways with capacity for rapid anterograde conduction whether or not they participate in the mechanism of the tachycardia
Pacing Indications to Prevent Tachycardia

Class I
Sustained pause-dependent VT, with or without prolonged QT, in which the efficacy of pacing is thoroughly documented

Class IIa
High-risk patients with congenital long QT syndrome

Class IIb
1. AV reentrant or AV node reentrant supraventricular tachycardia not responsive to medical or ablative therapy
2. Prevention of symptomatic, drug-refractory, recurrent atrial fibrillation in patients with coexisting sinus node dysfunction
Pacing Indications to Prevent Tachycardia

Class III

1. Frequent or complex ventricular ectopic activity without sustained VT in the absence of the long QT syndrome

2. Torsade de Pointes VT due to reversible causes
Class I

Recurrent syncope caused by carotid sinus stimulation; minimal carotid sinus pressure induces ventricular asystole of >3 seconds' duration in the absence of any medication that depresses the sinus node or AV conduction.
Hypersensitive Carotid Sinus and Neurocardiogenic Syncope

Class IIa

1. Recurrent syncope without clear, provocative events and with a hypersensitive cardioinhibitory response

2. Significantly symptomatic and recurrent neurocardiogenic syncope associated with bradycardia documented spontaneously or at the time of tilt-table testing
Hypersensitive Carotid Sinus and Neurocardiogenic Syncope

Class III

1. A hyperactive cardioinhibitory response to carotid sinus stimulation in the absence of symptoms, or in the presence of vague symptoms such as dizziness, light-headedness, or both.

2. Recurrent syncope, light-headedness, or dizziness in the absence of a hyperactive cardioinhibitory response.

3. Situational vasovagal syncope in which avoidance behavior is effective.
Children, Adolescents and Patients with Congenital Heart Disease

Class I

1. Advanced second- or third-degree AV block associated with symptomatic bradycardia, ventricular dysfunction, or low cardiac output

2. Sinus node dysfunction with correlation of symptoms during age-inappropriate bradycardia. The definition of bradycardia varies with the patient's age and expected heart rate

3. Postoperative advanced second- or third-degree AV block that is not expected to resolve or persists at least 7 days after cardiac surgery
Class I

4. Congenital third-degree AV block with a wide QRS escape rhythm, complex ventricular ectopy or ventricular dysfunction

5. Congenital third-degree AV block in the infant with a ventricular rate <50 to 55 bpm or with congenital heart disease and a ventricular rate <70 bpm

6. Sustained pause-dependent VT, with or without prolonged QT, in which the efficacy of pacing is thoroughly documented
Children, Adolescents and Patients with Congenital Heart Disease

Class Ila

1. Bradycardia-tachycardia syndrome with the need for long-term antiarrhythmic treatment other than digitalis

2. Congenital third-degree AV block beyond the first year of life with an average heart rate <50 bpm or abrupt pauses in ventricular rate that are two or three times the basic cycle length, or associated with symptoms due to chronotropic incompetence

3. Long QT syndrome with 2:1 AV or third-degree AV block

4. Asymptomatic sinus bradycardia in the child with complex congenital heart disease with resting heart rate <40 bpm or pauses in ventricular rate >3 seconds

5. Patients with congenital heart disease and impaired hemodynamics due to sinus bradycardia or loss of AV synchrony
Children, Adolescents and Patients with Congenital Heart Disease

Class IIb

1. Transient postoperative third-degree AV block that reverts to sinus rhythm with residual bifascicular block

2. Congenital third-degree AV block in the asymptomatic infant, child, adolescent, or young adult with an acceptable rate, narrow QRS complex, and normal ventricular function

3. Asymptomatic sinus bradycardia in the adolescent with congenital heart disease with resting heart rate <40 bpm or pauses in ventricular rate >3 seconds

4. Neuromuscular diseases with any degree of AV block (including 1st degree AV block), with or without symptoms, because there may be unpredictable progression of AV conduction disease
Children, Adolescents and Patients with Congenital Heart Disease

**Class III**

1. Transient postoperative AV block with return of normal AV conduction

2. Asymptomatic postoperative bifascicular block with or without first-degree AV block

3. Asymptomatic type I second-degree AV block

4. Asymptomatic sinus bradycardia in the adolescent with longest RR interval <3 seconds and minimum heart rate >40 bpm
Hypertrophic Cardiomyopathy

Class I

Class I indications for sinus node dysfunction or AV block as previously described.

Class IIa

None

Class IIb

Medically refractory, symptomatic hypertrophic cardiomyopathy with significant resting or provoked LV outflow obstruction.
Hypertrophic Cardiomyopathy

Class III

1. Patients who are asymptomatic or medically controlled.

2. Symptomatic patients without evidence of LV outflow obstruction.
Dilated Cardiomyopathy

Class I

Class I indications for sinus node dysfunction or AV block as previously described.

Class IIa

Biventricular pacing in medically refractory, symptomatic NYHA class III or IV patients with idiopathic dilated or ischemic cardiomyopathy, prolonged QRS interval (greater than or equal to 130 milliseconds), LV end-diastolic diameter greater than or equal to 55 mm, and ejection fraction less than or equal to 35%.
Dilated Cardiomyopathy

Class III

1. Asymptomatic dilated cardiomyopathy

2. Symptomatic dilated cardiomyopathy when patients are rendered asymptomatic by drug therapy

3. Symptomatic ischemic cardiomyopathy when the ischemia is amenable to intervention
After Cardiac Transplantation

Class I
Symptomatic bradyarrhythmias/chronotropic incompetence not expected to resolve and other Class I indications for permanent pacing

Class IIa
None

Class IIb
Symptomatic bradyarrhythmias/chronotropic incompetence that, although transient, may persist for months and require intervention

Class III
Asymptomatic bradyarrhythmias after cardiac transplantation.
Case One: 72 Year Old Male

- Resting heart rate of 40 bpm. Rhythm: ______
- Frequent falls, slight confusion
Case Two: 60 Year Old Female Two Weeks Post MI

- Rhythm ________________
- History syncope

![ECG Image]
Case Three: 45 Year Old Male During Exercise

- Rhythm __________________________
- Complains of shortness of breath, weakness
Pacing Codes and Modes Concepts
Upon completion of this preceptorship the participant should be able to:

- State what the first four positions of the NBG code represent and their respective applications.
- Explain the concept and benefits of AV synchrony.
- Describe the basic concepts of pacemaker timing intervals.
Pacing Codes and Modes Concepts:

Agenda

- Single Chamber Modes
- Dual Chamber Modes
- Non-Tracking Modes
- Rate Modulation/Rate Tracking Mode
Pacing Codes and Modes Concepts:

Agenda

- Single Chamber Modes
- Dual Chamber Modes
- Non-Tracking Modes
- Rate Modulation/Rate Tracking Mode
### The NASPE/BPEG Generic (NBG) Code

<table>
<thead>
<tr>
<th>Position</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
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</thead>
<tbody>
<tr>
<td>Category</td>
<td>Chamber(s) Paced</td>
<td>Chamber(s) Sensed</td>
<td>Response to Sensing</td>
<td>Programmability, rate modulation</td>
<td>Antitachyarrhythmia Function(s)</td>
</tr>
<tr>
<td>Letters Used</td>
<td>O-None</td>
<td>O-None</td>
<td>O-None</td>
<td>O-None</td>
<td>O-None</td>
</tr>
<tr>
<td></td>
<td>A-Atrium</td>
<td>A-Atrium</td>
<td>T-Triggered I-Inhibited</td>
<td>P-Simple Programmable</td>
<td>P-Pacing (antitachyarrhythmia)</td>
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<tr>
<td></td>
<td>V-Ventricle</td>
<td>V-Ventricle</td>
<td>D-Dual (T+I)</td>
<td>M-Multi-Programmable</td>
<td>S-Shock</td>
</tr>
<tr>
<td></td>
<td>D-Dual (A+V)</td>
<td>D-Dual (A+V)</td>
<td></td>
<td></td>
<td>C-Communicating</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>D-Dual (P+S)</td>
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<tr>
<td>Manufacturer’s Designation Only</td>
<td>S- Single (A or V)</td>
<td>S- Single (A or V)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
VOO

- Ventricular pacing
- No sensing
- Ventricular asynchronous pacing at lower programmed pacing rate
VVI

- Ventricular pacing
- Ventricular sensing
- Sensed intrinsic QRS inhibits ventricular pacing
- Pacemaker syndrome, a consideration in VVI pacing
Single Chamber Timing Intervals

Interval (ms) = 60,000 / rate (ppm)

60,000 / 60 ppm = 1000 ms
Single Chamber VVI

Vp Vp Vp Vs Vp

V Ref

V-V

Automatic Interval

Escape Interval
AAI

- Atrial pacing
- Atrial sensing
- Intrinsic P wave inhibits atrial pacing

Atrial lead
Single Chamber Timing Interval: AAI

Ap  PVC  Ap  As  Ap

A  Ref
A-A

Automatic Interval  Escape Interval
Pacing Codes and Modes Concepts: Agenda

- Single Chamber Modes
- **Dual Chamber Modes**
- Non-Tracking Modes
- Rate Modulation/Rate Tracking Mode
• Pacing in both the atrium and ventricle
• Sensing in both the atrium and ventricle
• Intrinsic P wave and intrinsic QRS can inhibit pacing
• Intrinsic P wave can “trigger” a paced QRS
Timing Intervals: Dual Chamber (DDD)

- $V-V =$ Lower Rate Limit
- $VA =$ Atrial Escape Interval
- $AV =$ AV Delay

$V-V = VA + AV$
DDD pacing

- Dual-chamber pacing capable of pacing and sensing in both the atrial and ventricular chambers of the heart
- 4 distinct patterns can be observed with DDD pacing
  - Sensing in the atrium and sensing in the ventricle
  - Pacing in the atrium and sensing in the ventricle
  - Sensing in the atrium and pacing in the ventricle (“P wave tracking”)
  - Pacing in the atrium and pacing in the ventricle
DDD pacing

- Example of sensing in both the atrium and the ventricle (inhibiting in both the atrium and the ventricle)
Complete Inhibition: A Sense, V Sense

AV Delay
VA Interval
LRL
DDD pacing

- Example of atrial pacing and ventricular pacing (no inhibition of pacing)
AV Sequential Pacing: A Pace, V Pace

AV Delay

VA Interval

LRL
DDD pacing

- Example of pacing in the atrium with sensing (inhibition of pacing) in the ventricle
Atrial Pacing with Conduction: A Pace, V Sense

- **AV Delay**
- **VA Interval**
- **LRL**
DDD pacing

- Example of sensing in the atrium (inhibition of atrial pacing) and pacing in the ventricle
P Synchronous Pacing: A Sense, V Pace

AV Delay

VA Interval

MTR

LRL
Timing Intervals: Dual Chamber Pacing

- AV Delay
- V-Blanking
- PVARP
- A-Blanking
- VA Interval
- V Ref
- URL
- LRL

Timing Intervals:

- AV Delay
- V-Blanking
- PVARP
- A-Blanking
- VA Interval
- V Ref
- URL
- LRL

Timing Intervals:

- AV Delay
- V-Blanking
- PVARP
- A-Blanking
- VA Interval
- V Ref
- URL
- LRL
• **Refractory Period:**
  - In pacing, a programmable parameter that controls the length of time following a paced or sensed beat, during which the pacemaker’s sensing circuit does not respond to sensed events.
    - PVARP=Post Ventricular Atrial Refractory Period=atrial refractory period
    - VRP=Ventricular Refractory Period
• **Blanking Period**
  • The interval of time following a paced output during which the pacemaker’s sense amplifiers are disabled
  • This timing parameter prevents cross chamber sensing
VDD

- Pacing in ventricle
- Sensing in both atrium and ventricle
- Intrinsic QRS inhibits ventricular pacing
- Intrinsic P wave can trigger the A/V delay and ventricular pacing
Pacing Codes and Modes Concepts:

Agenda

- Single Chamber Modes
- Dual Chamber Modes
- **Non-Tracking Modes**
- Rate Modulation/Rate Tracking Mode
DDI

- Pacing in the atrium & ventricle
- Sensing in both atrium and ventricle
- NO tracking of P waves (no constant AV delay)
- Used primarily for atrial tachyarrhythmias and mode switching algorithms
Pacing Codes and Modes Concepts:

Agenda

- Single Chamber Modes
- Dual Chamber Modes
- Non-Tracking Modes
- Rate Modulation/Rate Tracking Mode
Rate Responsiveness/Adaptive-Rate Pacing

- In Rate Responsive pacing, sensors detect changes in physiologic needs and increase the pacing rate accordingly.

- The sensor
  - Sensors are used to detect changes in metabolic demand.
  - Sensors sense motion (piezoelectric crystal or accelerometer) or use a physiologic indicator, e.g., minute ventilation.

- The algorithm
  - Within the software of the pacemaker.
  - Uses the input from the sensor to determine the appropriate paced heart rate for the activity.
Goals of Choosing a Pacing Mode

- **Desire to maintain AV synchrony**
  - DDD mode is best to provide AV synchrony

- **Preservation of AV synchrony requires:**
  - Viable atrium and
  - Patient must not have chronic/permanent atrial tachyarrhythmias
Any questions?
Rate Responsiveness/Adaptive-Rate Pacing

• In Rate Responsive pacing (modes ending with “R”), sensor(s) in pacemaker are used to detect changes in physiologic needs and increase the pacing rate accordingly

• The sensor
  • Sensors are used to detect changes in metabolic demand
  • Sensors sense motion (piezoelectric crystal or accelerometer) or use a physiologic indicator, e.g., minute ventilation

• The algorithm
  • Within the software of the pacemaker
  • Uses the input from the sensor to determine the appropriate paced heart rate for the activity
VVIR Timing

- Shortened Sensing Windows at High Rates
Example of Dual-Chamber Rate-Responsive pacing
• Sensor Rate Controls VA Interval

Lower Rate
60 ppm

Sensor Pacing
110 ppm
A DDDR pacemaker has two or more indicators of a patient’s metabolic need:

- Sinus node – the best indicator, as it is physiologic
- Input from the sensor(s) within the pacemaker
Upper Rate Operation: Pacemaker Wenckebach

- **As**
- **Vp**
- **AV**
- **PVARP**
- **TARP**
- **Maximum Tracking Rate**

Maximum Tracking Rate: 80

www.pacericd.com
Upper Rate Operation: Pacemaker Wenckebach (4:3 Block)

TARP
AV Delay
VA Interval
MTR
Upper Rate Operation: 2:1 Block
Pacemaker Mediated Tachycardia

- Rapid ventricular pacing secondary to retrograde conduction
Retrograde Conduction

Conduction of an electrical impulse from the ventricles to the atria through the heart’s conduction system.
Conditions Required for PMT

• Loss of A-V Synchrony
• Intact V-A Conduction
• V-A Conduction Time > programmed PVARP
Initiators of Retrograde Conduction

- Retrograde conduction is caused by loss any loss of AV synchrony, such as the following:
  - PVC (Retrograde conduction)
  - Oversensed P wave
  - Undersensed P wave
  - Loss of Atrial Capture
  - EMI
  - Magnet Application or Removal
PMT Prevention

- Program longer PVARP
  - PVARP after PVC
- Use PMT prevention scheme
- Need to make a programming change, or PMT will recur
Further Questions?